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Napoleon's Theorem, Shakespeare's Theorem, and Desargues's Theorem

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ABSTRACT

A very short and inevitably successful proof of Napoleon's theorem is given in terms of complex algebra. Another two related theorems, also concerned with centroids, are then proved by using an even simpler vector method. I eponymize these theorems to Shakespeare and Bacon in order to obey Stigler's law of eponymy. Finally, Desargues's theorem is related to the 3D monocular effect.

My aim in this brief note is to entertain and perchance to educate rather than to produce something new under the sun.

Consider a triangle ABC, labelled anticlockwise in the order A, B, C. (See Fig. 1.) Construct three equilateral triangles CBP_1, ACP_2, and BAP_3 external to ΔABC. Then the centroids G_1, G_2, G_3 of these three equilateral triangles form another equilateral triangle which I shall call the *derived* Napoleonic triangle. Someone who respected the Godfather, named the result "Napoleon's theorem" and therefore, by Stigler's Law of Eponymy (Stigler, 1980, "eponymy is always wrong", see also Good, 1985), we infer that it was more likely to have been discovered by Henry VIII. One proof was given in this journal recently by Boyd and Raychowdhury (1992).

It is intuitively obvious in advance that a short and automatic proof can be obtained by the machinery of complex algebra (if no mistakes are made!). This proof might not be too familiar though I would be surprised if it hasn't been discovered many times in the last hundred years so I give it with no claim to originality. I describe the "machinery" in three sentences, followed by the proof in four sentences.

A complex number z can be used to denote either a point in the Argand diagram (complex plane) or the vector $\vec{Oz}$ from the origin to that point, or, by the definition of a vector, any vector obtained from $\vec{Oz}$ by parallel displacement. Thus $\vec{AB}$ can be written as B – A (where B and A are complex numbers). For present purposes, O can be anywhere except "at infinity".

The line segment $\vec{CP_1}$, can be obtained by rotating the segment $\vec{AB}$ about C through an angle $\pi/3$ (anticlockwise); therefore $P_1 = C + \omega(B - C)$ where $\omega = \exp(\pi i/3)$. Therefore

$$G_1 = \frac{1}{3}[C + B + C + \omega(B - C)] = \frac{1}{3}[B(1 + \omega) + C(2 - \omega)]$$

and by "symmetry",

$$G_2 = \frac{1}{3}[C(1 + \omega) + A(2 - \omega)].$$

Therefore

$$\vec{G_1G_2} = G_2 - G_1 = \frac{1}{3}[A(2-\omega) - B(1+\omega) + C(2\omega - 1)].$$

Similarly,

$$\vec{G_2G_3} = \frac{1}{3}[A(2\omega - 1) + B(2 - \omega) - C(1 + \omega)$$

and this is seen to be ω^2 $\vec{G_1G_2}$ (an anticlockwise rotation of $\vec{G_1G_2}$ by $2\pi/3$) by using the equations $\omega^3 = -1$ and $\omega^2 = \omega - 1$.

Napoleon's second theorem (for example, Coxeter and Greitzer, p. 64) states that a similar result is true if the original equilateral triangles are all reflected in their "bases" BC, CA and AB. (The "inner" Napoleon theorem.) This can be proved by essentially the same argument as above, as the reader can verify. (Just change the sign of ω.)

Coxeter and Greitzer (1967, p. 166) prove that the outer and inner Napoleon derived triangles have the same centroid. This again follows "automatically" from the "complex" method because

$$\frac{1}{3}(G_1 + G_2 + G_3) = \frac{1}{9}\{[B(1+\omega) + C(2-\omega)] + [C(1+\omega) + A(2-\omega)] + [A(1+\omega) + B(2-\omega)]\} = \frac{1}{3}(A + B + C)$$

so the centroid of the outer derived Napoleonic triangle is at the centroid of the original triangle ABC, and similarly so is the centroid of the inner derived Napoloeonic triangle.

For a short history of Napoleon's theorem and allied matters, with many references, see Wetzel (1992).

Sometimes the most elementary use of vectors, without even appealing to inner products or vector products, is more powerful than the use of complex numbers. This is because vectors are defined in any number of dimensions. (For the advanced use of vectors, in fact Grassmanians, in geometry, see Forder, 1941.) This (elementary) method is illustrated by the proof of the following result which I shall call "Shakespeare's theorem" so as to bridge the "two cultures" (the humanities and the sciences) while continuing to obey Stigler's law. It could also be called a shrinkage theorem.

Given n points A_1, A_2, ..., A_n in d dimensions ($d = 1, 2, 3, ...$), let G_i denote the centroid of the (n -1) points obtained by omitting A_i. Then the construct consisting of G_1, G_2, ..., G_n is similar (in the standard technical sense of Euclidean geometry) to that consisting of A_1, A_2, ..., A_n and is scaled down by a factor n-1. The two constructs have the same centroid. Moreover, corresponding sides are "antiparallel", that is, parallel but oriented in opposite directions. The theorem is illustrated in Figure 1 for the case $n=4$, $d=2$. (The case $n=3$ is familiar and the case $n=2$ is trivial.) To visualize Figure 2 as a theorem about a tetrahedron ($n=4$, $d=3$) instead of a quadrilateral, it is better viewed with only one eye. That eye acts as a center of projection. With both eyes open one has more visual cues (conscious or subconscious) that a diagram is in the plane of the paper.

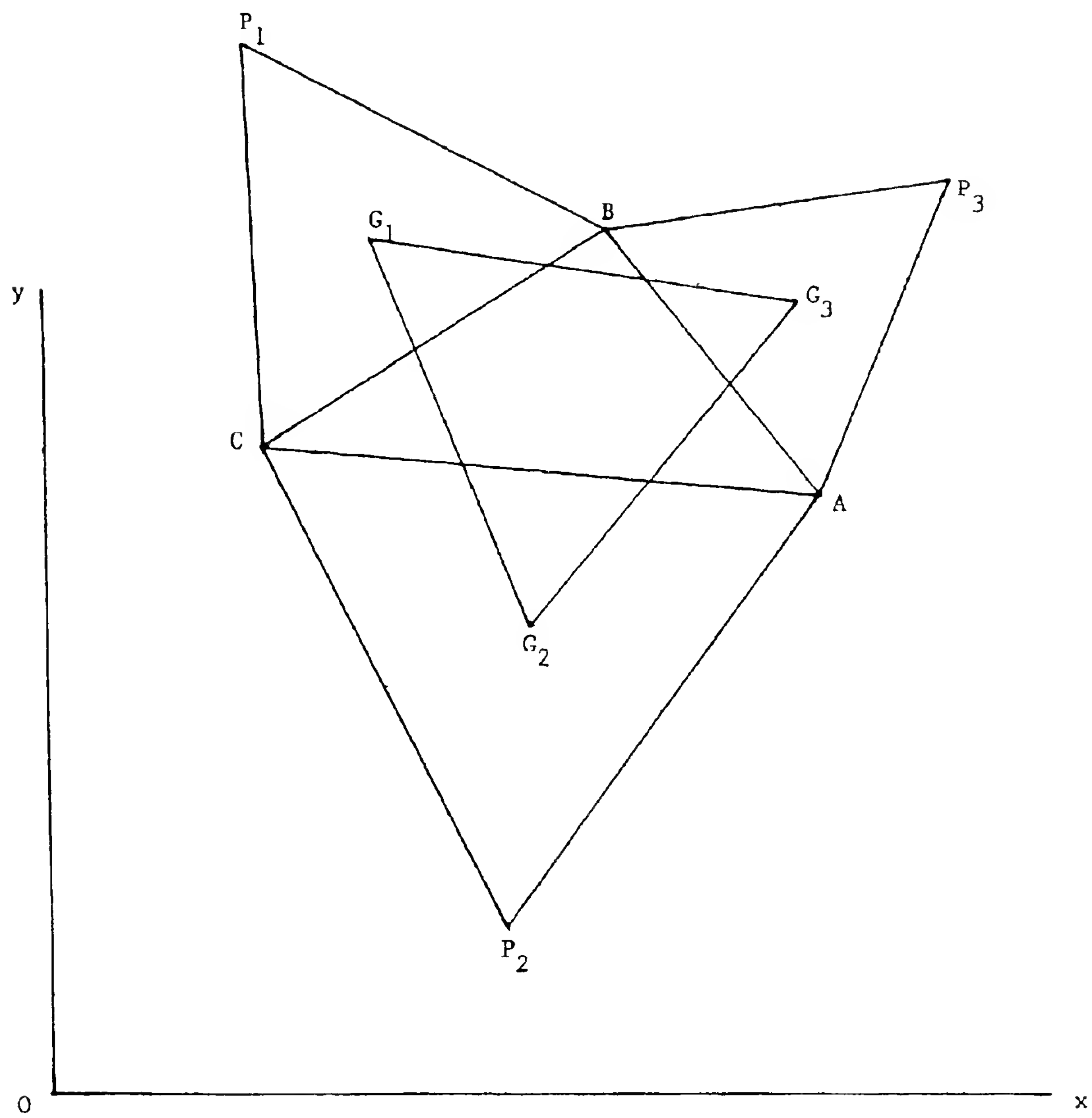

FIGURE 1. Napoleon's theorem.

Proof of Shakespeare's theorem. We have

$$G_1 = \frac{1}{n-1}(A_2 + A_3 + \ldots + A_n)$$

and

$$G_2 = \frac{1}{n-1}(A_1 + A_3 + A_4 + \ldots + A_n)$$

so

$$\overrightarrow{G_1G_2} = G_2 - G_1 = \frac{1}{n-1}(A_1 - A_2)$$

$$= \frac{1}{n-1}\overrightarrow{A_2A_1}$$

and similarly

$$\overrightarrow{G_iG_j} = \frac{1}{n-1}\overrightarrow{A_jA_i}$$

for all pairs i and j. This equation expresses the required "antiparallelism" and a scaling down of the original construct by a factor (n-1). The main part of the

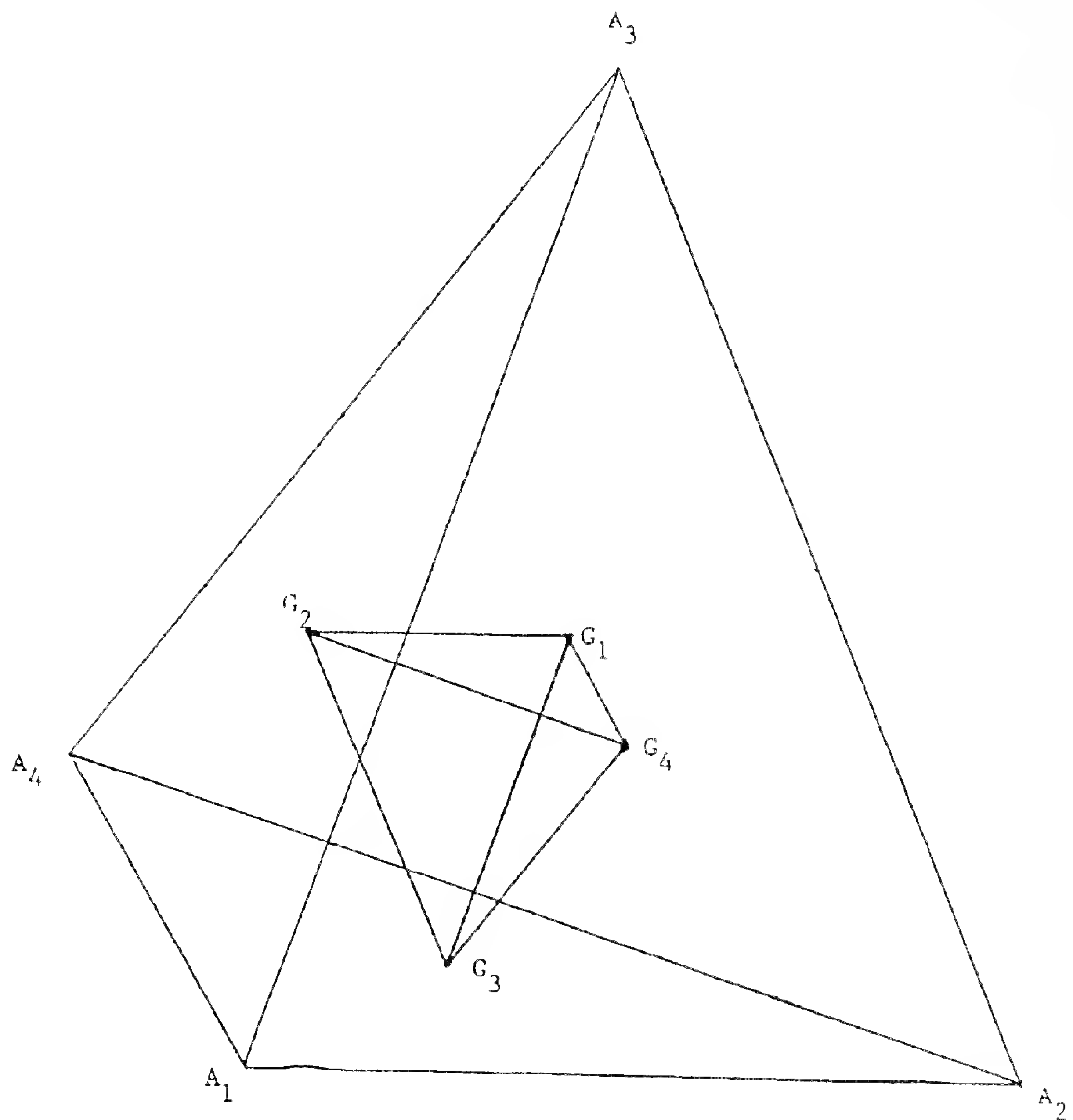

FIGURE 2. The shrunken quadrilateral or tetrahedron. If the theorem were used repeatedly, the successive tetrahedra would shrink down to a point, namely G.

theorem now follows from the fact that two figures (each connected and without "hinges") are congruent if one can be obtained from the other by a length-preserving transformation (see, for example, Coxeter and Greitzer, 1967, p. 80).

The proof that the two constructs have the same centroid is too simple to include here.

Bacon's Theorem. The lines $\overrightarrow{A_iG_i}$ (i = 1, 2, ..., n) *are concurrent.*

Proof. Denote by G the centroid of $A_1, A_2, \ldots, A_n$. We have

$$G = (A_1 + A_2 + \ldots + A_n)/n$$
$$= (1/n)\,A1 + (1 - 1/n)G_1 .$$

Because the sum of the two coefficients is 1, it follows that G lies on the line $\overrightarrow{A_1G_1}$ and similarly on the lines $\overrightarrow{A_iG_i}$ for all i. *A fortiori* these n lines are concurrent and we have brought home the Bacon.

Excuse for the eponymy. It has often been conjectured that "Shakespeare" was a pseudonym for Francis Bacon.

Statistical interpretation. Figure 2 and the allied discussion have an obvious interpretation (in a multivariate way) in terms of the Introduction of Efron (1982). The similarity (in the technical sense) of the shrunken structure to the original one makes it intuitively obvious that the Jackknife technique of "missing one out" cannot lead to an improved estimate of the population mean. But, as Efron's Introduction implies, the Jackknife (and Bootstrap) were not proposed in relation to the population mean.

"Projecting back" to one eye. Desargues's famous theorem in projective geometry states that if two triangles are in perspective from a point then they are also "in perspective from a line" (see, for example, Coxeter and Greitzer, 1967, p. 70). The theorem is thus expressible in terms of the incidence relations in only two dimensions, but its proof is not. When the axioms of incidence in three dimensions are assumed, the proof is simple because the two planes of the triangles meet in a line. See, for example, Baker (1943), pp. 22-23. This proof can be made especially intuitive if the diagram is viewed from one eye and is projected backwards into three dimensions. This visual technique of backward projection was used above to transform a quadrilateral into a tetrahedron. For another example, especially elegant, of viewing a two-dimensional diagram as if it were in three dimensions so as to give greater insight, see Honsberger (1976, page 19) who acknowledges Frank Bernhart.

The technique provides a bridge between geometry and artistic appreciation, as may very well have been noticed by Desargues (1591-1661) who was an architect as well as a geometer. For when a picture has strong perspective features, such as a road receding into the distance, it can be made to look especially three-dimensional when viewed with one eye closed. This is found to be true by a high fraction of male viewers. For a write-up of a sampling experiment on this topic see Good (1986). This "3D monocular effect" was noticeable by 28 out of the 37 subjects questioned, mostly male. Professor Dr. Anton Hajos of the University of Giessen, who is an expert on human visual perception, informed me in 1987 (i) that the 3D monocular effect is known, (ii) that it is less clear for photographs taken at a great distance, and (iii) that it is less noticeable by female subjects. He did not confirm that the effect is strongest for pictures containing a "lot of perspective". He cited Hofmann (1925, page 434 ff).

Only recently did I notice the relationship between this property of visual perception and the visual proof of Desargues's theorem although I became aware of the latter in about 1936 while attending a course on projective geometry given by F.P. White in Cambridge, England. My excuse for taking more than fifty years to notice the relationship is that unfortunately one tends to keep the two cultures in watertight compartments.

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Spawning Behaviors in *Luxilus albeolus* and *Luxilus cerasinus* (Cyprinidae)

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ABSTRACT

With our descriptions of spawning activities in *Luxilus albeolus* and *Luxilus cerasinus*, the reproductive behaviors of all nine species in *Luxilus* have been documented. Based on these accounts of behaviors there are two lineages in the genus (furrowing species where females rise to the water surface after the clasp, and non-furrowing species where females do not rise to the surface after the clasp). Reproductive behaviors in *L. albeolus* and *L. cerasinus*, each chronologically resolved into a sequence of six categories (Interim, Approach, Alignment, Run, Clasp and Dissociation) exemplified a successful spawn as defined by the clasp.

INTRODUCTION

With the exception of *Luxilus albeolus* and *Luxilus cerasinus*, the breeding behaviors of the nine species of the cyprinid genus *Luxilus* have been documented (Johnston and Birkhead, 1988; Kendall and Goldsboro, 1908; Miller, 1967; Outten, 1957; Pflieger, 1975; Raney, 1940; Robison and Buchanan, 1988; Smith, 1979). For this study the spawning behaviors in *L. albeolus*, which forms a furrow (equals hollow of Kendall and Goldsboro, 1908), are described and compared to those in the surface substrate spawner, *L. cerasinus*.

MATERIALS AND METHODS

Breeding behaviors of 12 *L. albeolus* and 11 *L. cerasinus* were observed over four nests of *Nocomis leptocephalus* in Pumpkin Creek (Dan-Roanoke River drainage), St. Rt. 86, 1 km N of St. Rt. 205, Pittsylvania Co., Virginia, 15 May 1987 (16.5 C) and 8 May 1993 (18.9 C). Behaviors were filmed above the surface of the water with Nuvicon-tube and CCD cameras equipped with zoom macrolenses and polarizing filters. Three hours of videotapes were played repeatedly, and frame by frame to establish spawning behaviors for each species. The categories, which identify a chronological sequence of spawning behaviors, follow Sabaj (1992): Interim (male only), Approach (female only), Alignment (orientation of a male and female), Run (female initiated), Clasp (flexure of male's body around the female), and Dissociation (separation following clasp). Behaviors other than those associated with the spawning sequence were considered disruptive of a successful spawn.

RESULTS

Descriptions of spawning behaviors over one nest on 15 May 1987, representative of activities seen on all nests, are presented by species and category.

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Luxilus albeolus

Interim: Six male *L. albeolus*, one after another, swimming against the water current, established territories in depressions in the irregular surface on the upstream slope of clean mound nests of *N. leptocephalus* that were not occupied at the time by attending males. Male *L. albeolus* either bulldozed or flicked pebbles aside with their snouts (mouths closed) or their cheeks to form spawning furrows ($\leq$2 cm deep) that eventually equalled the total length of a male.

Approach: The female approached the male in the spawning furrow either from the side or from downstream. Females did not approach a furrow when the male was engaged in territorial defense.

Alignment: As the female moved into the furrow, the male shifted laterally (1-2 cm) away, allowing her to position herself in the center of the furrow. Then the male, coordinating his swimming to that of the female, aligned alongside, and pressed his snout to hers.

Run: The Run was initiated by the female. The female swam forward with the ventral portion of her body appressed to the substrate of the furrow. Her forward movement did not exceed more than one-half the length of her body. The male followed the female, keeping his snout firmly affixed to hers. The female then arched her head upwards ($\leq$ 30 degrees) as she turned her body away from the male. As her snout came up, she twisted so that her dorsum was appressed to the male's anterior flank, and her caudal peduncle to the substrate.

Clasp: The male initiated the spawning clasp. As the female arched her head upwards, the male tilted his body prior to curving his caudal peduncle over her back. He drove his posterior flank into the female's side between her pectoral and pelvic fins. In this position, the male's body was in a sigmoid configuration. With further contraction (from snout to caudal peduncle) his body formed a semicircle around the female with sufficient force to cause her mouth to gape.

Dissociation: The female, directed vertically, continued to rise into the water column until she broke the surface. The male assumed a position over his spawning furrow.

Disruptive behaviors of a successful spawn were: non-contact head displacement, non-contact body displacement, head/body butt, chase, and parallel swim between male *L. albeolus* as described elsewhere by Maurakis and Woolcott (1993) for *N. leptocephalus* . If tilting by the male occurred prior to the run, the female moved from the furrow. Combat and/or aggressive displays with other species (male *Campostoma anomalum*, *L. cerasinus*, and *Lythrurus ardens*) also disrupted a spawning sequence.

Luxilus cerasinus

Interim: In contrast to the behavior in male *L. albeolus*, male *L. cerasinus* did not form furrows but hovered over their territories (discrete pebble areas) on the upstream slope of a nest of *N. leptocephalus*.

Approach: If a female approached the male from downstream he maintained his position. If she approached from the side he proffered his spawning area by moving laterally away from her. When she was directly over the spawning site he moved back into place.

Alignment: Like Alignment in *L. albeolus*, the male *L. cerasinus* coordinated his swimming with that of the female. After positioning himself against her side over the substrate, he pressed his snout against hers.

The behaviors associated with the Run and the Clasp in *L. cerasinus* were like those described for *L. albeolus*, except that they did not occur in a furrow. Unlike *L. alebolus*, female *L. cerasinus* did not rise towards the surface during Dissociation. Like in *L. albeolus*, the aggressive and combat behaviors in which territorial male *L. cerasinus* engaged conspecific males, and those with *L. ardens* and *Phoxinus oreas*, were disruptive of successful spawning.

DISCUSSION

There are two lineages within *Luxilus* (furrowing species where females rise to surface after clasp, and non-furrowing species where females do not rise to surface after clasp). In addition to *L. albeolus*, furrowing species include *Luxilus cardinalis* (Miller, 1967; Robison and Buchanan, 1988), *Luxilus chrysocephalus* (Hankinson, 1932; Robison and Buchanan, 1988; Smith, 1979), *Luxilus cornutus* (Raney, 1940), *Luxilus pilsbryi* (Pflieger, 1975), and *Luxilus zonatus* (Pflieger, 1975). Like *L. cerasinus*, the species *Luxilus coccogenis* (Outten, 1957) and *Luxilus zonistius* (Johnston and Birkhead, 1988) do not form furrows.

We do not agree with Johnston (1989) who included *Luxilus* species and those of *Campostoma* with pebble nest-building species. The furrowing behavior in some species of *Luxilus* and the pit digging in *Campostoma* species are not forms of pebble nest-building (i.e., construction of mound and pit/ridge nests) as described by Maurakis et al. (1992). Pebble nest-building in cyprinids is a behavior that is an overt movement of pebbles by the use of jaws (keratinized inner mandibular epithelium; McGuire, 1993) in males in species of *Exoglossum*, *Nocomis*, and *Semotilus*. Keratinized inner mandibular epithelium is absent in *L. cerasinus* and *L. cornutus*, nor does it occur in *Campostoma* species which dig pits (McGuire, 1993).

A furrow may create reduced water currents similar to those that facilitated the sinking of gametes into interstices in spawning pits of nests of *Semotilus* species, and those in nests of *N. leptocephalus* as reported by Maurakis et al. (1992). Additionally, the furrow provides a clean protected substrate for spawning and deposition of eggs.

Our observations of the spawning behaviors in *L. albeolus* and *L. cerasinus* support Sabaj (1992), who proposed that his six sequential categories of breeding behaviors for pebble nest-building cyprinids may be applied to the spawning behaviors of other species that spawn over gravel substrates. His categories provided a clear and definitive framework for describing the spawning behaviors in these two lithophilous spawners.

Luxilus albeolus and *L. cerasinus* spawned over the upstream slope of nests when male *N. leptocephalus* were either present or not. As small size eggs and the larger eggs of *N. leptocephalus* were found in the upstream slopes of nests on both dates, it is presumed that *N. leptocephalus* had completed spawning at the unattended nest. Neither *L. albeolus* nor *L. cerasinus* are regarded as obligatory symbionts of *N. leptocephalus*, a questionable mating association described for

Hydrophlox lutipinnis and *N. leptocephalus* by Wallin (1989). Not only have we observed *H. lutipinnis* spawning on nests in the absence of attending male *N. leptocephalus*, but the latter species is present in drainages where *H. lutipinnis* does not occur.

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The Role of Peroxidase in Tolerance to Ozone in Bean (*Phaseolus vulgaris L.*)[1]

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ABSTRACT

Seven accessions of bean (*Phaseolus vulgaris* L.) plant introductions, (PI's) 169-735, 171-790, 206-982, 370-569, 414-831, 209-493, and BBL-290 (cultivar Bush blue lake-290) were used to determine whether the peroxidase enzyme in plants is a contributing factor to a mechanism for ozone (O_3) resistance. These seven accessions were chosen based on variations in ozone tolerance in previous studies. Pre-treatment of plants with 0.2 ppm O_3/2 h significantly increased peroxidase activity in leaves and provided protection against a subsequent exposure to 0.4 ppm O_3/2 h. A positive correlation ($r = 0.95$) between increased peroxidase activity and enhanced O_3 tolerance in tolerant (T) and intermediate tolerant (IT) groups was found. The electrophoretic study showed two new bands of isoperoxidases that were induced only by O_3 exposure, and were predominant for the T, and IT group. These new bands may be involved in the O_3 resistance mechanism.

INTRODUCTION

A definitive role for peroxidase in plants has eluded plant scientists so far. Many researchers have reported the general involvement of peroxidases in lignin synthesis (Cattle and Kolatukuddy 1982; Egley et al., 1983; Harkin and Obst, 1973) and oxidation of endogenous indole acetic acid (Gramdow and Langen-Schwich, 1983) in beans (*Phaseolus vulgaris* L.). The varietal differences in ozone tolerance (Tingey et al., 1976; Beckerson et al., 1979; Butler and Tibitts et al., 1979a,b; Reinert et al., 1984) suggest that there is an inherent mechanism in plants that determines ozone susceptibility (Mebrahtu et al., 1990).

Peroxidase was cited as a screening parameter for different physiological stresses. An elevated peroxidase level is induced by cold, drought, hypoxia, and salt stress (Highkin, 1969; Rakova et al., 1969; Stutle and Todd, 1967; Siegl et al., 1966). Peroxidase activity was also used as a biochemical marker for different types of pollution (Curtis and Howell, 1971 ; Poddleskis et al., 1984). Ozone (O_3)was reported to have an effect on the level of peroxidase activity of several plant species (Dass and Weaver, 1968; Poddleskis et al., 1984; Tingey et al., 1975; Curtis et al., 1976; Egley et al.,1983; Cattle and Kolatukuddy, 1982). In very few cases, some

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1 Contribution of Virginia State University, Agricultural Research Station Journal Article Series No. 167. Petersburg, VA. 23803.

2 Corresponding author, P. O. Box 9259, Virginia State University, Petersburg, VA 23806, phone: (804) 524-6715. The use of any trade name varieties, and/or vendors does not imply the exclusion of other products or vendors that may also be suitable.

TABLE 1. Selected Bean (*Phaseolus vulgaris* L.) genotypes and their tolerance to ozone.

Accession	O_3 Tolerant (T)	Intermediate Tolerant (IT)	Sensitive (S)
PI169-735	+		
PI171-790	+		
PI206-962		+	
PI370-569		+	
PI414-831			+
PI209-493			+
BBL-290			+

effect on the isoperoxidase profile was reported (Shanon 1948; Curtis and Howell 1971; Curtis et al., 1976; Endress et al., 1980; Dass and Weaver 1972; Rier et al., 1983, 1987; Sood et al., 1985). Ozone was found to modify the patterns of peroxidase in ozone-sensitive plants more rapidly than in ozone-insensitive plants (Curtis et al., 1976).

The existence of multiple forms of peroxidase in plants was known for a number of years (Shanon, 1948), but the relationship of individual isoenzymes to specific biological functions is not clear. An increase in total peroxidase activity was often found when pathogens infect plants whose response can be classified as resistant (Andreev and Shaw, 1965; Farkas and Stahmann, 1966; Novackey and Hampton, 1968; Uritani and Stahmann, 1961). Such increases were caused by the activity of certain specific isoenzymes, as reflected by staining intensity in polyacrylamide gels (Seevers et al., 1971; Daly et al., 1970).

Toxic oxygen species, produced as by-products in many biological reactions and/or by air pollutants such as O_3, can lead to damage of almost all cell components:- DNA, lipid membrane, and protein (Tepperman and Dunsmuir, 1990; Storz, et al., 1990). Inducible defenses to counter oxidative damage in prokaryotic and eukaryotic cells were reported (Chan and Wiss, 1987; Keyse and Tyrrel, 1989; Christman et al., 1985), but the mechanisms by which the cell receives and responds to oxidative stress have not elucidated.

The objective of the present study was to investigate the possible role of peroxidase in tolerance to O_3 in selected bean accessions. The differences in peroxidase activity and in isoenzyme patterns were determined after ozone exposure and mechanical injury in sensitive and tolerant accessions.

MATERIALS AND METHODS

Plant Materials:

The seven bean accessions used in this study were selected based on a previous screening study for O_3 sensitivity (Reinert et al., 1984). These bean accessions and their degree of sensitivity to O_3 are listed in Table 1. Three seeds from each accession were planted in a 12 cm plastic pot with a 2:1 (v/v) mixture of gravel and buffered redi-earth, and seedlings were thinned to one plant per pot after emergence. Plants were grown in an environmentally controlled room with 28/22°C day/night temperature and illuminated by metal halide lamps providing 350

$\mu Em^{-2}S^{-2}$ photosynthetic photon flux density throughout the study, except under fumigation conditions .

Fumigation of plants with O_3:

Plants were exposed to O_3 under environmentally controlled conditions at 16 and/or 18 days from planting for 2 h at 24 ± 2°C, 65 ±3% relative humidity, and a light intensity of 400 $\mu Em^{-2}S^{2}$ photosynthetic photon flux density provided by mixed incandescent and fluorescent lighting. Exposure to O_3 was initiated after plants were pre-equilibrated in the chamber for 2 h. Control plants were placed in a similar chamber, except that these plants were exposed to charcoal filtered air for 6 h. Ozone was generated by passing dry oxygen through an ozone generator (Griffin model GTC-A1 generator, Griffin Technics corp., Lodi, NJ). Ozone concentration in the growth chamber at plant height was monitored with a 8410 O_3 analyzer (Monitor Labs, Inc., San Diego, CA). The monitor was calibrated every 2 weeks with a Model 1003-pc ozone calibrator (Dasibi Environ Corp., Glendale, CA). After each fumigation with O_3, plants were returned to the control environmental room.

In the first experiment, 18-day old plants were exposed to a single acute exposure of 0.6 ppm (v/v) O_3 for 2 h to determine the changes in peroxidase activity under screening conditions described by Reinert et al., (1984). The leaves of whole plants were extracted and assayed for peroxidase activity. In the second experiment, 18-day old plants were exposed to 0.0, 0.1, 0.2, 0.4 and 0.6 ppm (v/v) O_3 for 2 h to study plant responses to different O_3 concentrations. In this experiment, the first trifoliate was collected, extracted and assayed for peroxidase activity. To study the effects of double exposure on the selected bean accessions, 16-day old plants were divided into four groups. The plants in the first and second group were pre-exposed to 0.1 and 0.2 ppm (v/v) O_3 for 2 h, followed by a second exposure of 0.6 and 0.4 ppm (v/v) O_3 for 2 h respectively, two days later. Plants in the third and fourth group were used as controls and were treated as described above. Trifoliates were collected and peroxidase activity was estimated.

Ozone-treated plants were visually assessed for percentage foliar damage by estimating the percentage of visible injury on a 0% to 100 % scale in increments of 5 % (Reinert et al., 1984).

To distinguish between the effects of O_3 treatments and mechanical injury, plants from each accession were mechanically wounded as described in detail by Ryan (1974). Injured leaves were harvested 24 h following wounding and assayed for peroxidase activity.

Enzyme assay and electrophoresis of the isoenzymes:

The leaves from each plant were excised and deveined, individually weighed (3-5 g), and homogenized in a Waring Model 7011 blender (100 ml steel blender cup at high speed for 30 sec.) using 4 ml of cold 10 mM potassium phosphate buffer pH 8.0 containing 0.8 M KCl per 1 g leaf (Curtis and Howell, 1971). The homogenate was centrifuged for 10 min at 20,000 x g. The supernatant was collected and assayed for total peroxidase activity. All steps in the tissue processing were carried out at 4°C. Peroxidase activity was determined according to the modified method of Machly and Chance (1954) using O-dianisidine in a DU-8 spectrophotometer (Beckman Instruments, Inc., Columbia, MD). The change in absorbance at 470 nm was recorded at 20 sec. intervals, and the reaction was linear

for 5 min. Peroxidase activity (PA) was determined by measuring the change in Δ OD_{470nm} min^{-1} g^{-1} fresh weight as described by DunLeavy and Urs (1978).

Gel electrophoresis (Davis, 1964) was performed on leaf extracts to determine the changes in isoenzyme profile caused by different treatments. Sodium ascorbate was added to the leaf homogenate to a final concentration of 50 mM and a portion of this solution was dialyzed against tris-glycine buffer (pH 8.3) in a 18 mm spectrapore membrane tubing (MW cut-off 3500 Dalton). Protein was determined in the dialyzed extracts using folin-phenol reagent (Lowery et al., 1951) and no significant differences in protein concentration were found among the three groups and between treatments. Details of gel electrophoresis procedures and staining are given elsewhere (Curtis and Howell, 1971; Habeck and Curtis, 1974). Immediately after the run was completed, the gels were removed and incubated for 15 min in a mixture of 0.1 % O-dianisidine reagent and 0.3 % H_2O_2 in a Na acetate buffer, pH 5.1 (Curtis and Howell, 1971). The gels were transferred to 7 % acetic acid for 1-3 min, then washed with distilled water, and photographed. Because of the large number of gels generated and the unavailability of a gel scanning densitometer, the results were summarized in a computer generated graph (Figure 4).

Experiments had four replications and were repeated twice. The collected data were subjected to analysis of variance as a randamized complete block design and least significant difference ($P=0.05$) was used to compare means. Correlations between observed variables were examined using linear regression analyses. Statistical analyses were performed using the general linear model (GLM), SAS program (Barr et al., 1976). A probability of <0.05 was required for significance in all statistical analyses.

RESULTS AND DISCUSSION

The induction of peroxidase activity (PA) by a single acute O_3-exposure was investigated and the results are presented in Figure 1. The data showed a significant increase in PA in O_3-treated plants, especially in the sensitive group (S, 370%). This increase was much higher than that of plants in the tolerant (T, 53%) and in the intermediate tolerant (IT, 86%) group. This significant increase in PA in sensitive plants may be due to leaf damage that was higher in the sensitive group throughout the study (Figure 3). Moreover, the data in Figure 1 also indicated that control plants in the T and IT groups had a significantly higher PA than that of the S group.

A significant increase in PA was observed in all mechanically injured plants (Figure 1). However, the T and IT group showed higher increases in the enzymatic activity than the S group. The data in Figure 1 also showed that the increase in PA caused by O_3-treatment was significantly higher than that of mechanically injured ones. The increase in PA following O_3-exposure has been reported earlier (Curtis et al., 1976; Tingey, 1975; Endress et al., 1980; Dass and Weaver, 1972; Curtis and Howell, 1971; Runeckles and Rosen, 1977a,b). The increase in PA by mechanical injury is in agreement with other research conducted on sunflower, *Helianthus annus* L. (Lipez,1970); tobacco, *Nicotiana tabacum* L. (Birecka et al., 1975); and sweet potato, *Ipomoea batatas* pair (Birecka et al., 1976).

To study the plant response to different O_3 concentrations, plants were exposed to 0.1, 0.2, 0.4 and 0.6 ppm O_3/2 h. Peroxidase activity increased as O_3 level

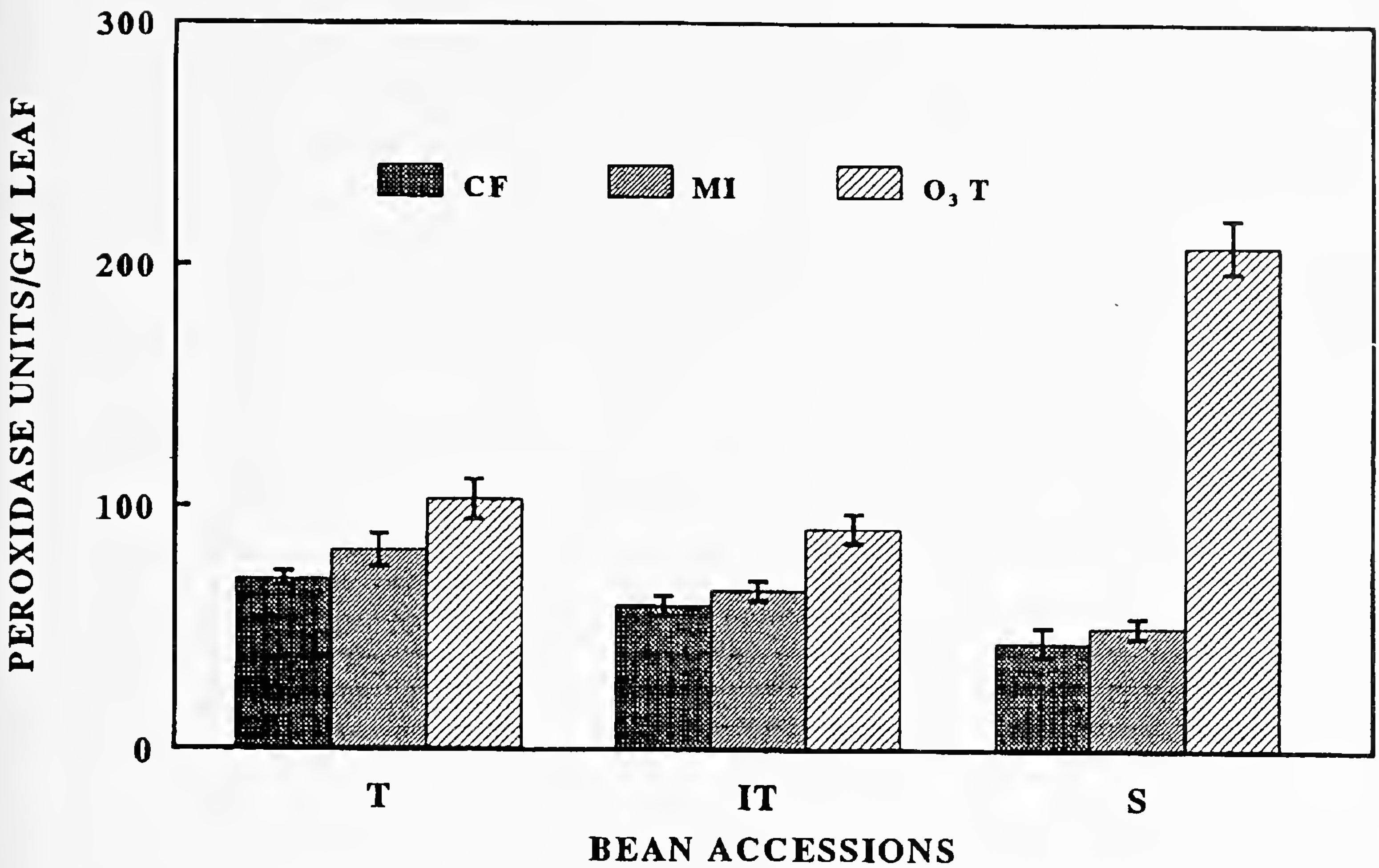

FIGURE 1. Effect of O3 and mechanical injury on the peroxidase activity in beans (*Phaseolus vulgaris* L.). CF; Charcoal Filter (control), O3 treated (0.6 ppm O3/ 2 h), MI; Mechanical Injury. T; Tolerant, IT; Intermediate Tolerant, and S; Sensitive accessions. Means of control and O3 treatment and means of control and mechanically injured plants are significantly different according to paired analysis at $p > 0.05$, LSD = 12 and 4.99 for O3 and mechanical injury, respectively.

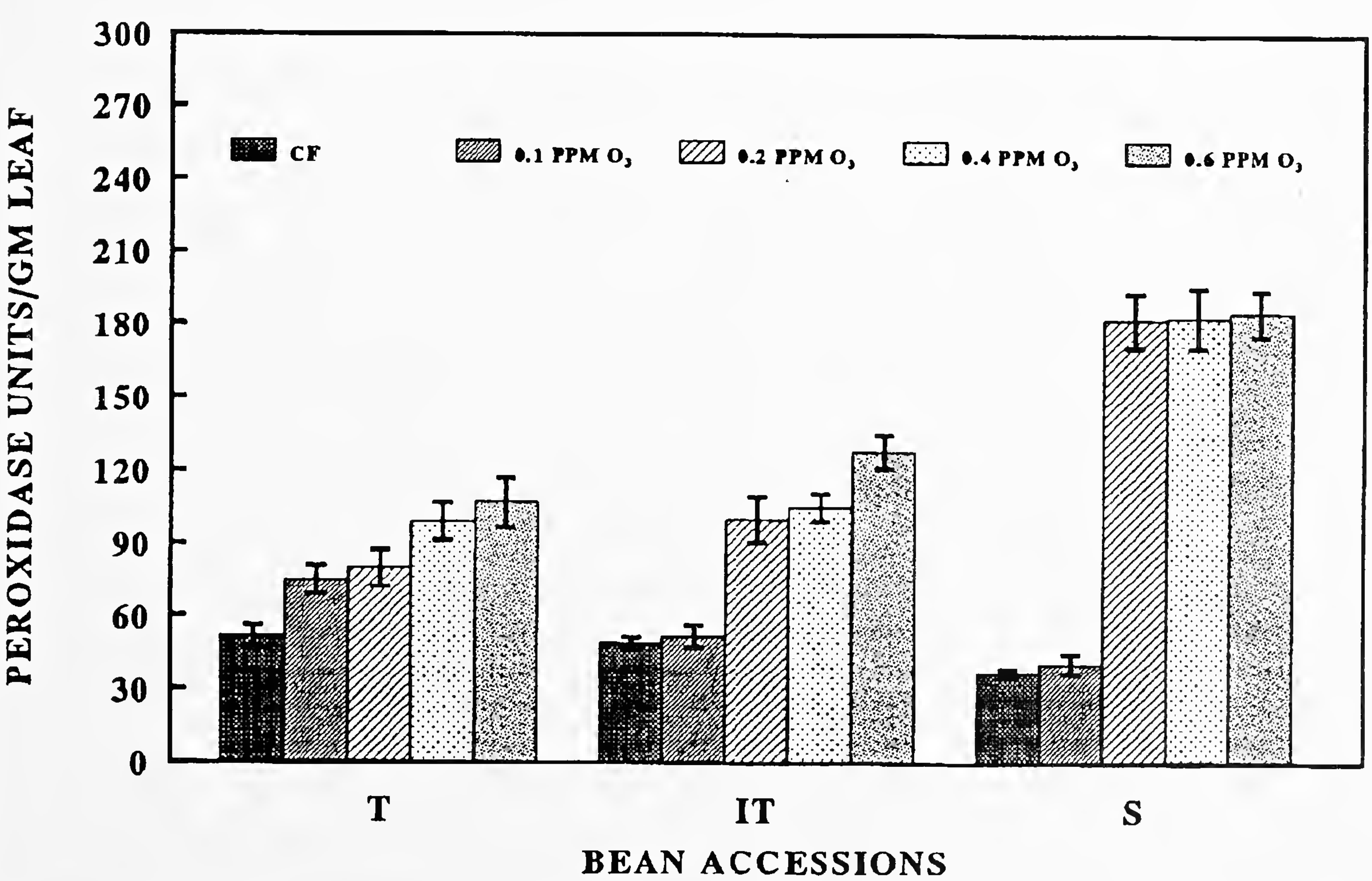

FIGURE 2. Effect of different O3 concentrations on the peroxidase activity in beans (*Phaseolus vulgaris* L.). CF; Charcoal Filter, 0.1, 0.2, 0.4, and 0.6 ppm O3/2 h. T; Tolerant, IT; Intermediate Tolerant, and S; Sensitive accessions.

TABLE 2. Induced peroxidase activity (PA) and percentage of injured leaf area (LD) of first trifoliate of bean exposed to 0.6 ppm O_3 or pre-exposed to 0.1 ppm/2 h at day 16 and followed 0.6 ppm O_3/2 h, two days later.

Tolerance Group[a]	Accession	Control PA	Control LD	0.6 ppm PA	0.6 ppm LD	0.1 and 0.6ppm PA	0.1 and 0.6ppm LD	LSD (0.05) PA	LSD (0.05) LD
T	169-735	45	0	104	70	125	60	19	18
	171-790	50	0	210	85	220	78	10	5
IT	206-982	45	0	129	90	156	90	25	2
	370-569	48	0	126	85	139	80	9	4
	414-831	53	0	136	65	146	80	9	13
S	209-493	40	0	183	100	191	100	8	5
	BBL-290	34	0	177	98	71	80	5	15

(Column groups fall under the spanning header "O_3 Concentration".)

[a]T: tolerance to O_3; IT: Intermediate tolerance to O_3; S: sensitive to O_3

increased (Figure 2). At 0.1 ppm O_3/2 h, the T group showed significantly higher increase in PA than the IT and S groups and no leaf injury was observed in all treated plants (Figure 3). Both the T and IT group showed a gradual increase in PA when O_3 concentration was gradually increased from 0.2 to 0.6 ppm/ 2 h (Figure 2). In contrast, sharp increases in PA were observed in the S group at 0.2 ppm O_3 / 2 h. This sharp increase was associated with significantly higher leaf injury (72% at 0.2 ppm O_3/2 h) compared to the T (9%) and IT (19%) groups, respectively (Figure 3). In addition, a significant positive correlation ($r = 0.95$) was found between leaf injury and the increase in PA at different O_3 concentrations.

Pre-exposing treatment (0.1 ppm O_3/2 h) for the IT and S groups caused a minor increase in PA that was insufficient to provide protection against the subsequent O_3-exposure. As indicated in Table 2, the 0.6 ppm and 0.1 and 0.6 ppm O_3/ 2 h treatments showed high foliar injury (83 - 99 %) in the S and IT groups. In contrast, a small but, significant reduction in leaf injury (11.5 %, $p < 0.05$) was observed for the T group.

A second exposure experiment was conducted with concentration of 0.2 ppm O_3/2 h 16 days from planting, followed by exposure to 0.4 ppm O_3/ 2 h two days later. The pre-induction of peroxidase by 0.2 ppm O_3/ 2 h allowed for significantly higher PA in the T and IT groups (Table 3). As a result, there was a significant decrease in foliar damage following the 0.4 ppm/ 2 h treatment in the T and IT groups which were pre-exposed to 0.2 ppm O_3. The data from these two groups confirm Runeckles and Rosen's (1977a,b) conclusion that pre-treatment with low doses of O_3 induced resistance to more concentrated acute-O_3-exposure.

The 0.1 ppm O_3 pre-exposure study showed that the pre-induction of PA was not significant and therefore did not help to protect plants in the IT and S groups against O_3 injury in the 0.1 and 0.6 ppm O_3/ 2 h treatment. In contrast, a significant reduction in leaf injury was found in plants in the T group. During pre-exposure

TABLE 3. Induced peroxidase activity (PA)and percentage of injured leaf area (LD) of first trifoliate of bean exposed to 0.4 ppm O_3 or pre-exposed to 0.2 ppm/2 hr at day 16 and followed 0.4 ppm O_3/2 hr, two days later.

Tolerance		O_3 Concentration							
		Control		0.4 ppm		0.2 and 0.4 ppm		LSD(0.05)	
Group[a]	Accession	PA	LD	PA	LD	PA	LD	PA	LD
T	169-735	45	0	60	20	85	13	19	5
	171-790	58	0	138	50	216	38	50	5
IT	206-982	45	0	125	45	229	31	69	6
	370-569	48	0	98	75	136	51	23	12
	414-831	53	0	94	21	198	15	47	4
S	209-493	40	0	108	98	128	90	19	7
	BBL-290	34	0	207	85	249	83	43	3

[a]T: tolerance to O_3; IT: Intermediate tolerance to O_3; S: sensitive to O_3

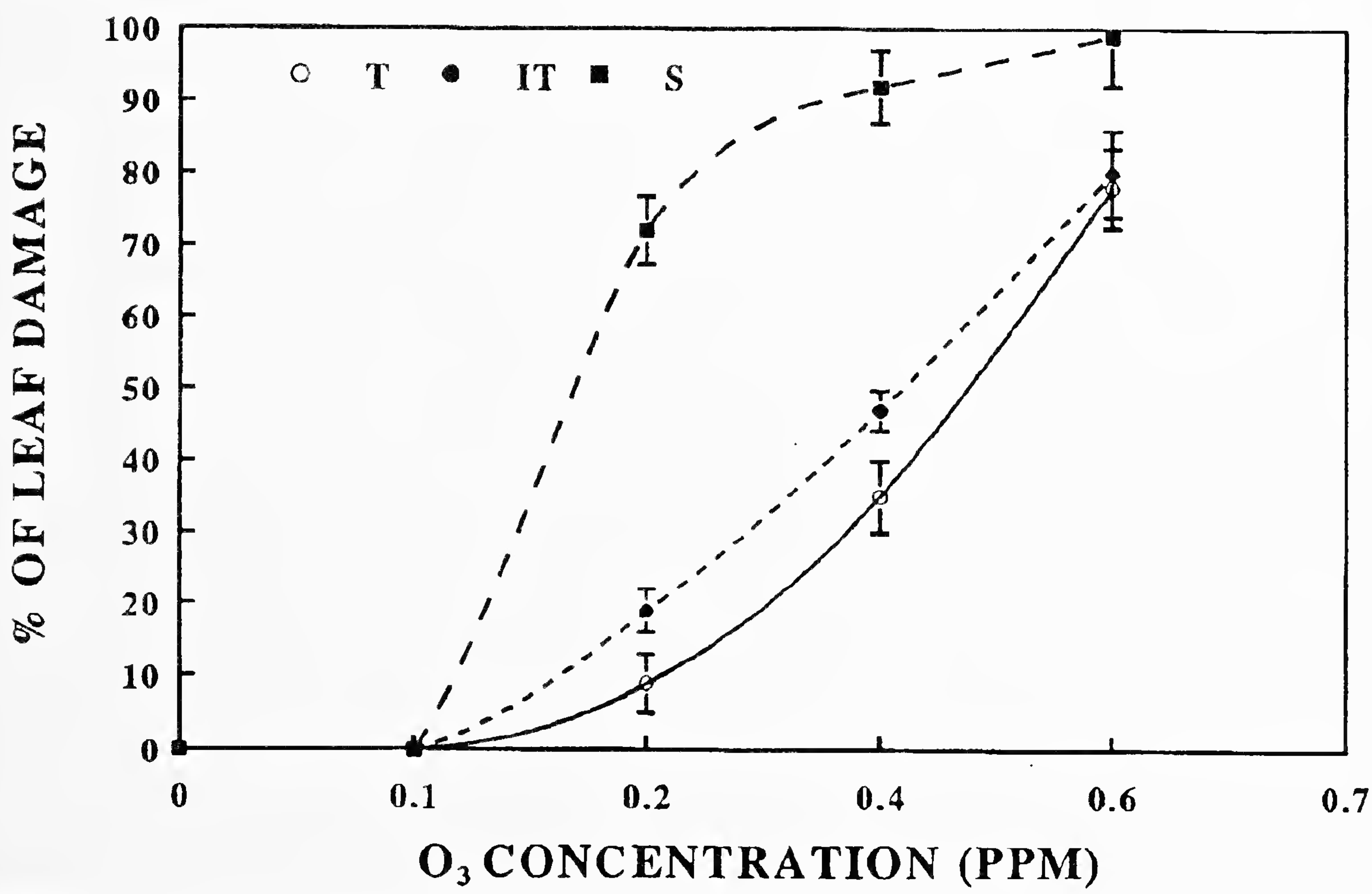

FIGURE 3. Percentage of leaf damage at different O_3 concentration in beans (*Phaseolus vulgaris* L.). T; Tolerant, IT; Intermediate Tolerant, and S; Sensitive accessions.

with 0.2 ppm, our study showed a possible relationship between increased levels of PA and enhanced tolerance to O_3 in the plants of the T and IT groups. The T and IT group showed moderate increases in PA by pre-exposure treatment and an average 28% reduction in foliar injury was observed. The sharp increase in PA and high foliar damage in sensitive plants suggests an alternative explanation of the association between peroxidase and foliar injury by O_3. The extent of injury to the

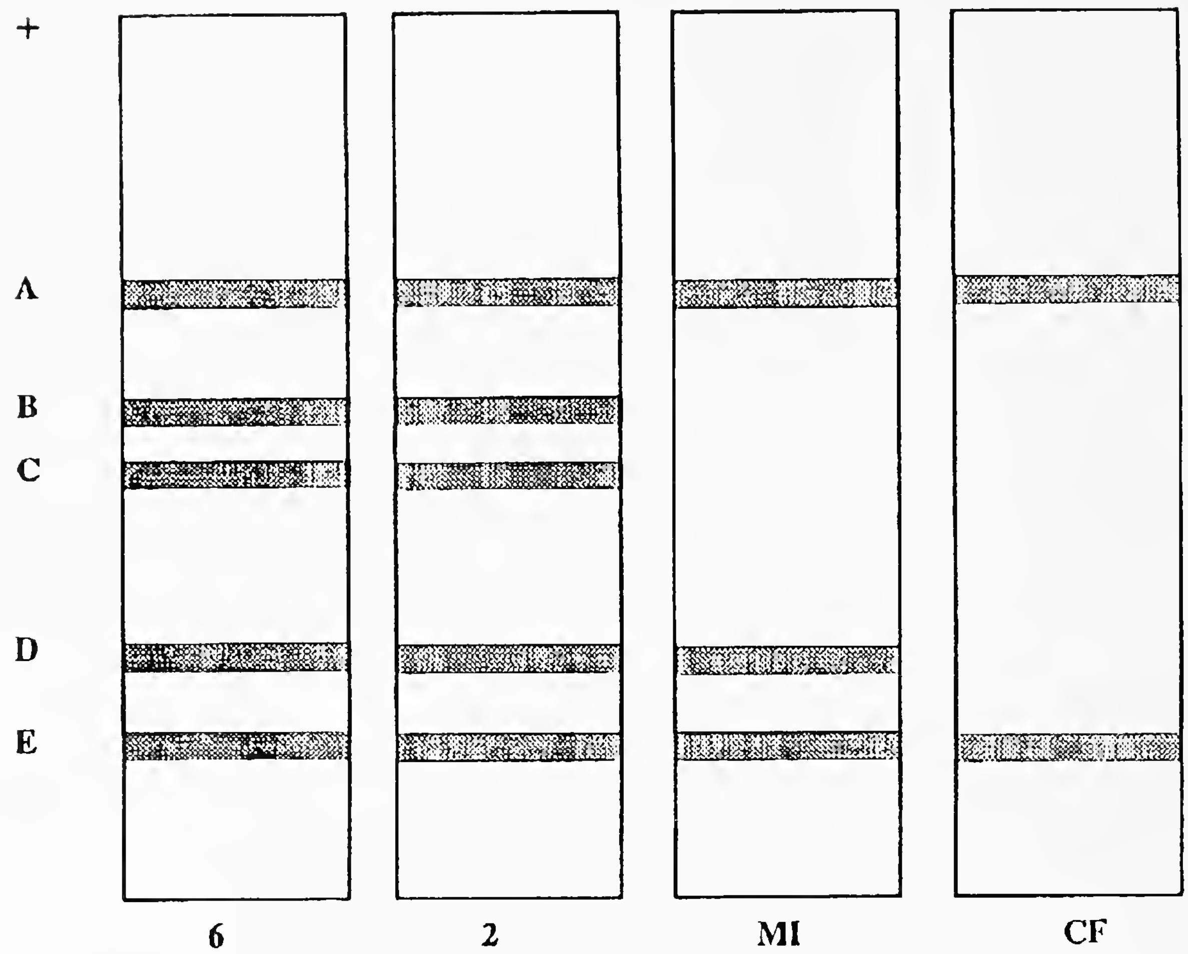

FIGURE 4. Gel electrophoresis representative of *Phaseolus vulgaris* isoperoxidase pattern following O_3 exposure. A, B, C, D, and E represent specific isoperoxidase bands. The four different treatments are designated as follows:CF; Charcoal Filter (control), 2, O_3-treated (0.2 ppm O_3/ 2 h); 6, O_3-treated (0.6 ppm O_3/ 2 h); MI; Mechanical Injury and the origin located on the top.

S group (65.5%) from low dose exposure showed a significant protection would be unlikely and leads us to speculate that the increase in PA in these plants may be a part of an injury response to O_3 rather than a protective mechanism (Nadolny and Sequeira 1980; Seevers et al., 1971). Since PA was increased by O_3 pre-treatment in tolerant and intermediate tolerant accessions, it suggests the presence of a factor(s) which control(s) the dose-dependent increase in PA with increasing O_3 concentration (Figure 2), and this factor(s) could be absent in sensitive accessions.

As seen in Figure 1, the increase in PA (19%) as a result of mechanical injury was lower than the increase in PA by O_3 exposure treatment (Figure 1). Thus, it was unlikely for mechanical injury to provide significant protection against O_3. However, leaves which had been mechanically injured showed O_3 damage only on the proximal end of the leaf. Leaf tissue on the distal side of the mechanical injury site showed little or no damage by O_3, while leaf tissue of the proximal side of the injury showed typical symptoms of O_3 phytotoxicity. However, results were extremely variable and statistically insignificant.

The effect of O_3 exposure and mechanical injury on the peroxidase isoenzymes are presented in Figure 4. Inspection of the stained gels revealed visual differences in band intensity between O_3-treated and control plants. All of the bands showed an increase in the stain intensity as results of O_3-exposure. Plants exposed to 0.6 ppm O_3/2 h showed the greatest amount of staining. Two new bands (B and C) were identified in the T and IT plants after O_3 exposure, and were similar in stain intensity in those two groups of plants. These two bands were absent in control and mechanically injured plants in the T, IT, and S groups, as well as in S accessions that was exposed to O_3 (Figure 4). Bands A and E were common to all accessions

with increasing stain intensity following both O_3 and mechanical injury treatments. The band D tended to be a variable among accessions and was induced by O_3 and mechanical injury treatments. Similar alterations in isoperoxidase profiles were reported earlier (Farkas and Stahman, 1966; Dass and Weaver, 1972; Endress et al., 1980; Curtis and Howell, 1971; and Curtis et al., 1976). However, no correlation between tolerance to O_3 and specific isozyme in beans was documented. Alterations in isoperoxidase profile were also observed in O_3-exposed callus (Sood et al. 1985, Rier et al. 1983, 1987).

Isoenzyme profiles are generally believed to be genetically controlled. Changes in the isoenzyme patterns due to changed environmental conditions or infections were explained by altered combinations of protein subunits to yield different molecular species or by activation or derepression of latent synthetic potentialities (Schwartz, 1966; Scandalios 1964).

It is suggested that some of the isoperoxidase induced by O_3 exposure may be a part of the mechanism for tolerance and missing in the O_3-sensitive plants. Consequently, the presence of these two bands may be responsible for the protection against O_3 injury rather than the increase in the total peroxidase activity.

The reason why plant peroxidases are more active under pollution is not known. Recently, the Oxy-R-controlled regulon of hydrogen peroxidase-inducible genes in *E. coli* was used as a model to study the cellular response to oxidative stress. When bacterial cells were treated with low doses of hydrogen peroxide, the synthesis of at least 30 proteins was induced, and the cell became resistant to subsequent doses of hydrogen peroxide, that would otherwise be lethal (Storz et al., 1990). Christman et al. (1985) reported that the expression of nine of these proteins induced by hydrogen peroxide treatment was under the control of the Oxy-R gene. Strains carrying deletions of Oxy-R were unable to induce the nine proteins and were hypersensitive to hydrogen peroxide and other oxidants (Storz et al., 1990). Some of the nine proteins that are regulated by the Oxy-R gene were identified and included catalase and alkyl hydroperoxide reductase (Morgan et al., 1986). The presence of similar systems in plants is possible. More research is needed in this area.

Several comparisons may be made between the reaction of peroxidases to air pollutants such as O_3 and to infection. Curtis et al. (1976) found that upon O_3 exposure, the PA of an O_3-tolerant cultivar of soybean was less affected than the activity of an O_3-sensitive cultivar, and this finding is in agreement with our finding. This also may be compared to the differences observed between plants resistant and susceptible to specific infection. Horsman and Wellburn (1977) reported that plants already exposed to a pollutant appear to be less responsive to new exposure as compared to plants coming from non-polluted environments, and this resembles the acquired resistance following an infection. Our investigation established similar correlations in beans for both O_3-tolerant and intermediate tolerant plants, and not for O_3-sensitive ones. Finally, the results showed a positive relationship between higher peroxidase levels, isoenzymes, and enhanced O_3-tolerance. This research is preliminary in nature but shows possible trends that may leads to an understanding of the mechanism of O_3-tolerance in plants. Further research is needed to determine the exact significance of pre-induced PA and its relevance to

O_3-tolerance. The inheritance of specific isoperoxidases that are induced by O_3-treatment (band B and C) is under investigation.

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Imaging Carbon and Nitrogen Concentrations and the Interdiction of Concealed Narcotics and Explosives

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ABSTRACT

I describe a new nuclear technique which produces images of elemental carbon (nitrogen) in concentrations and with surface densities typical of concealed bulk narcotics (terrorist explosives.) The signal is the totality of high-energy gamma rays detected with time after irradiation of a target pixel by a ~30 (~50) MeV beam from an electron accelerator. There are no significant interfering signals. I present 180 2 x 2 cm^2 pixel intensity images of a kilo of cocaine (125 grams of SEMTEX).

INTRODUCTION

Postal packages, airline baggage, cargo containers, and vehicles could be effectively screened for illicit drugs if carbon concentrations could be detected, since cocaine and heroin are ~66% carbon by weight. The ubiquity of carbon in our environment requires that images of these concentrations be made since form often indicates function (Sullivan, 1924). Further, quantities of carbon imaged in unusual venues (e.g., automobile fenders, airplane wings, etc.) have a high probability of being contraband. Finally, the addition of conventional transmission x-ray images to those of carbon concentrations would improve the screening efficiency and decrease the number of time consuming hand searches. The Carbon Camera, which is described below, addresses this scenario.

The attack on Pan Am 103 in 1988, which resulted in that plane's destruction and 270 deaths (Report, 1990), momentarily re-energized governmental efforts to develop effective screening technology for explosives concealed in airline passenger baggage. However, none of these incipient "tombstone technologies" have succeeded in detecting, let alone imaging, quantities of explosives as small as the ~300 grams of SEMTEX used in that attack. Equally troubling is Iraqi's reckless, random, and undocumented seeding of the Kuwait desert with land mines which pose a continual hazard to animals, civilians, and demolitions mercenaries. These two faces of terrorism motivated the invention of the Nitrogen Camera described here.

The Carbon and Nitrogen Cameras have much in common. In each a succession of pixels on the surface of an object suspected of concealing carbon or nitrogen concentrations are irradiated intermittently and sequentially by a beam from an electron accelerator. Scintillation detector counts registered between pulses are attributed to the carbon or nitrogen content of the previously irradiated pixel. When aggregated these individual pixel counts form an intensity image. X-rays, produced with the high-energy nuclear-probing photons, detected in transmission produce a conventional mass-density image.

The Carbon Camera differs from the Nitrogen Camera in that it uses a lower energy accelerator beam and has effectively no interfering signals. In the Nitrogen

Camera, carbon produces the sole significant contaminating signal from which the nitrogen signal must be quantitatively untangled.

In what follows, I first discuss the physics on which the Carbon and Nitrogen Cameras are based. I then present experimental proof of the technique as I have demonstrated it to date, clearly indicating what remains to be verified. I end by making a gloss of the enabling technology from which a working prototype can result.

THE PHYSICS

Although the Carbon and Nitrogen Cameras share much with conventional cameras -- photographic, x-ray, and positron -- they rest on different physics. Recall that in the photographic camera visible light with energy of a few eV is scattered by an object, is manipulated by a variety of optical devices, falls onto an aperture, and is recorded on electronic or chemical media. While in the x-ray camera, photons of a few keV are scattered as they pass through an object and fall unmanipulated onto an aperture where they are recorded. In the PET camera, a radioisotope, with a half-life of hour to days, is injected into an object. Decay positrons lose energy by bremsstrahlung in a succession of collisions, finally annihilating into two oppositely-directed half MeV gamma rays whose signals are manipulated to produce a three-dimensional image.

In the Carbon and Nitrogen Cameras, high-energy photons are flashed into a small area of an object in which they create a variety of radioisotopes, many of which give rise to gamma rays. Excited isotopes go to their ground state by emitting gamma rays. Beta decay produces electrons and positrons and in turn a plethora of bremsstrahlung gamma rays, logarithmically increasing in number with decreasing energy. Positrons annihilate into gamma rays. All these gamma rays detected in a brief interval after irradiation constitutes the signal for the Carbon and Nitrogen Cameras.

For the Carbon Camera, the irradiation of all known materials by photons with energies above ~17 MeV but below ~30 MeV produces only one isotope, in appreciable quantity which beta-decays rapidly - its half-life is 20.2 milliseconds. That radioisotope is boron-12, its production and decay reactions are,

$$\gamma + {}^{13}C \rightarrow {}^{12}B + p\,;\ {}^{12}B \rightarrow {}^{12}C\,\nu_e\ e^-,$$

and its cross section increases linearly with photon intensity and dramatically with energy. The bremsstrahlung and de-excitation gamma rays recorded immediately after irradiation is taken as our carbon marker.

A quantitative example confirms the promise of this technique. If we irradiate a graphite block with monoenergetic photons of ~25 MeV only two reactions are induced, each with roughly equal probability: ${}^{13}C(\gamma, p)\,{}^{12}B$ -- the "signal" -- and the "noise" -- ${}^{12}C(\gamma, n)\,{}^{11}C$ whose half life is ~1,200 seconds. During the first 20 milliseconds after irradiation, half of the produced boron-12, but only ~0.00002 of the carbon-11 will decay. The signal-to-noise in the first 20 ms will be ~600/1, because carbon-13 constitutes only ~1% of all naturally occurring carbon.

In reality the situation is more complicated. First, these reactions have different cross sections which are only vaguely known. Second, photons produced by an electron beam in a radiator are not monochromatic, their number varying not only with the electron beam energy and intensity, but also with the radiator

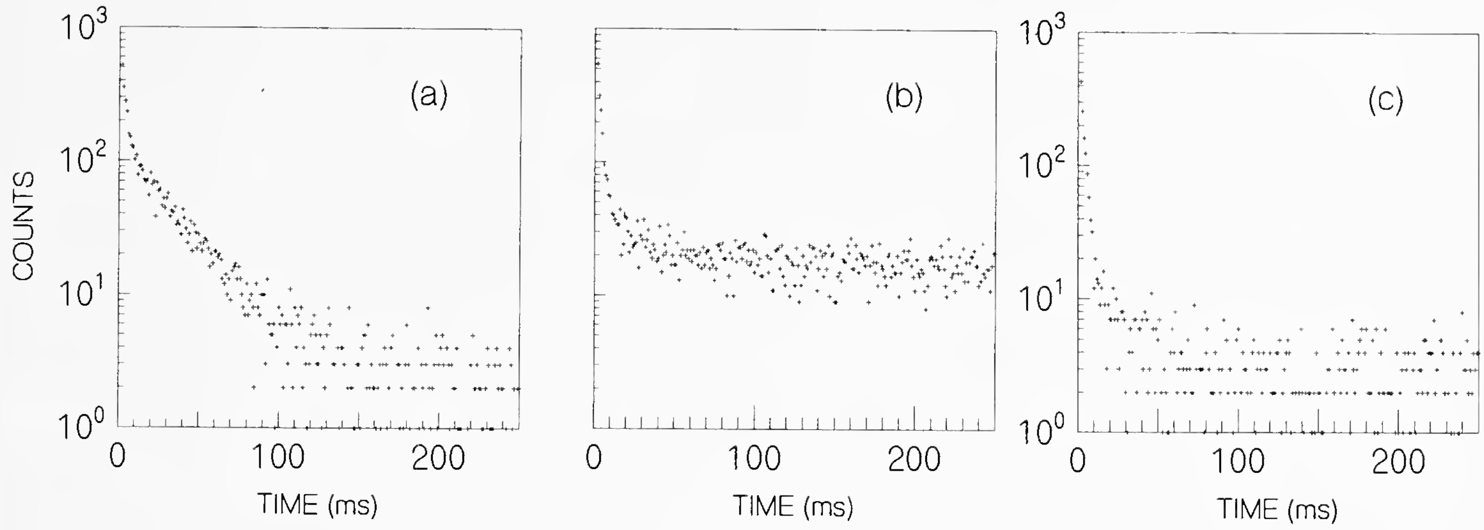

FIGURE 1. Time evolved spectra for 26.7 MeV electrons on (a) graphite, (b) Boraxo, and (c) KNO_3.

geometry and material. Third, extraneous radiation is produced during and immediately after the acceleration process which produce counts in the detectors. Finally, the wide variety of elements present in most material, when irradiated, contribute long-lived "noise" elevating the background on which our signal sits.

THE CARBON CAMERA

A burst of ~30 MeV electrons traversing matter generate neutrons and photons, both virtual and real, which produce a variety of radionuclei. In the first few milliseconds the neutrons are slowed by collisions and captured by nuclei giving rise to gamma rays. After some tens of milliseconds most gamma rays come from the decay of long-lived radioisotopes. In the time interval between these two salient regimes, boron-12 decays ejecting beta rays which bremsstrahlung and some of the time leaves carbon-12 in an excited state. Bremsstrahlung and de-excitation gamma rays constitute the Carbon Camera signal.

I have experimentally verified this scenario at the Alfven Laboratory's 50 MeV electron racetrack microtron of the Royal Institute of Technology in Stockholm, Sweden (Rosander, 1982). The beam, up to ~20 mA of electrons, was delivered in 3 μs-long pulses at a rate of 1.2 Hz. A 1 mm thick tantalum radiator could be inserted in the beam to provide real photons. The detectors, 12.5 cm diameter fast photomultiplier tubes coupled to thick organic scintillators, were located ~50 cm upstream from the targets. Detector signals were energy discriminated, summed and fed into a multiscalar board resident in the back plane of a 486/33 personal computer.

The time evolved spectra of three targets irradiated by multiple (~100) 1 mA bursts of 26.7 MeV electrons are seen in Fig. 1. These spectra share (1) a dominate fast peak, ~1.5 ms half-life, from radiative neutron capture and (2) a small persistent background which increases with the number of beam bursts, the beam current, and the target matter density. What remains after these two features are taken into account is the Carbon Camera signal in Fig. 1(a) which constitutes 65.9 ± 1.1% of the total counts and exhibits a half-life of 20. 13 ± 0.24 ms.

If carbon is to be used as a marker in screening for narcotics there must be few sources of similar signals. A computer search (Brookhaven, 1989) was made for

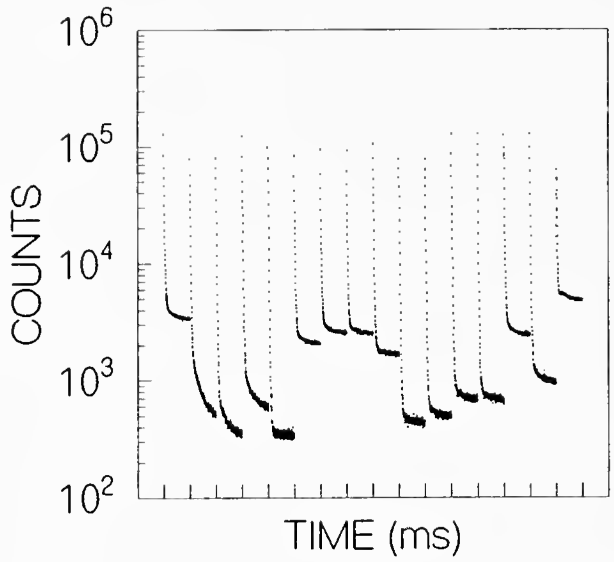

FIgure 2. Time spectra (from left to right) of aluminum, medium plastic mine, small plastic mine, small metal mine, air, granite, earth, sand, KBr, magnesium, $CaSO_4$, $NaBiO_8$, water, iron, Teflon and lead obtained with 50 MeV electrons.

photo-nuclear reactions induced with 30 MeV photons on stable isotopes whose isotopic abundance was >1%. All reactions producing up to four nucleons, as well as those involving radiative neutron capture, were screened for beta emitters which decayed with half-lives < 100 ms. The reactions $^{13}C(\gamma, p)\ ^{12}B$, $^{11}B(n,\gamma)\ ^{12}B$, and $^{14}N(\gamma,2p)\ ^{12}B$ were identified, where the boron-12 half-life is ~20.2 ms. The last reaction has a threshold of 25.1 MeV and so is still weakly produced at 30 MeV (see Fig. 1(c)). The second reaction is not troublesome (see Fig. 1(b)) and further the environmental abundance of boron is small (Trower, 1993).

Experimental spectra for a variety of objects, including all but one (titanium) of the ten most abundant elements in the earth's crust (99.48% by weight) as well as 17 other elements, showed only one signal, $^{14}N(\gamma,2n)\ ^{12}N$, in addition to those mentioned above, when a ~50 MeV electron beam was used (Trower, 1993). A typical suite of time evolved spectra are shown in Fig. 2, nitrogen being present in the melamine land mine simulants.

These multiple-pulse data had encouraging implications for single-burst excitation needed for imaging: (1) short-time noise is brief so its time domain can be excluded; (2) long-time noise is small and well behaved so can be ignored; and (3) only the carbon signal is appreciable.

For imaging, a bending magnet was inserted into the beam line and its power supply programmed to produce 15 equally spaced vertical sequentially ascending beam spots. A constant speed motor drove a worm screw which moved a 2 cm thick, 25 x 25 cm^2 aluminum plate horizontally and transverse to the beam at a speed of 1 cm/s. The plate supported the targets and provided background counts. About 70% of the electron beam was contained in a ~2 cm diameter circle, which increased to ~3 cm with the radiator interposed. With this saw tooth scanning pattern 180 pixel images were produced in ~2.5 minutes.

Figure 3 shows the response of a 251 g, 3 x 3x 5 cm^3 pyrolytic graphite block viewed end-on by the 30 MeV probing electrons. A clear image of the carbon, ~56 counts on a ~12 count background, is evident. These data are the raw counts registered in a 30 ms interval beginning 10 ms after irradiation. A similar block of table salt attached to the middle of the left most side of the plate is not in evidence.

A solid 996 g, 24 x 10 x 4 cm^3 block of cocaine (Narkotikaroteln, 1992) was mounted vertically in the middle of the plate and irradiated with 30 MeV electrons. The resulting intensity image, seen in Fig. 4, clearly shows the presence of this drug.

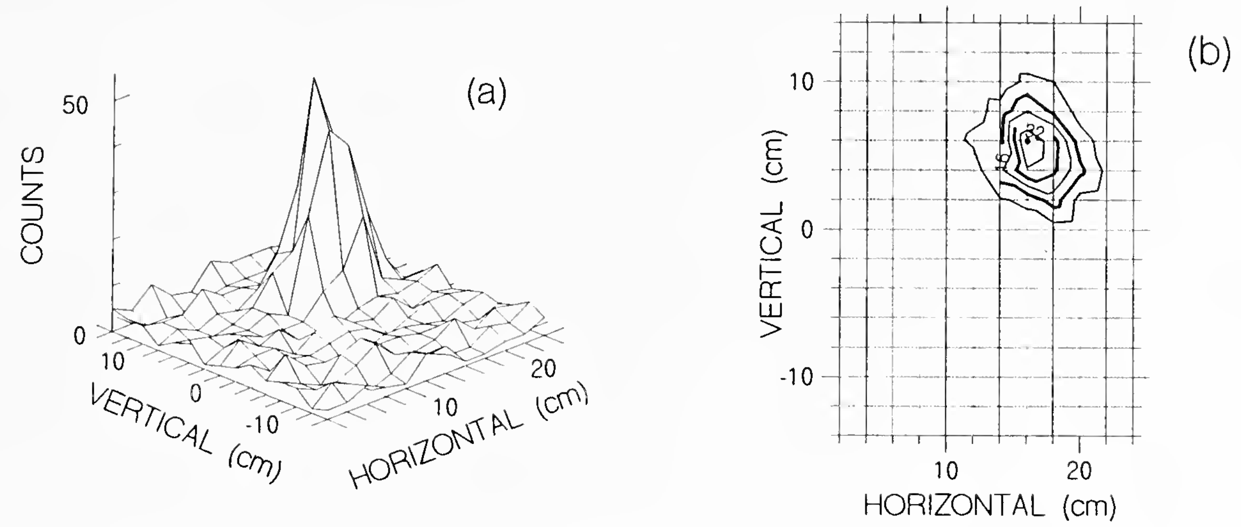

FIGURE 3. Response from graphite (upper right) and salt (mid-far left): (a) intensity image and (b) contour projection.

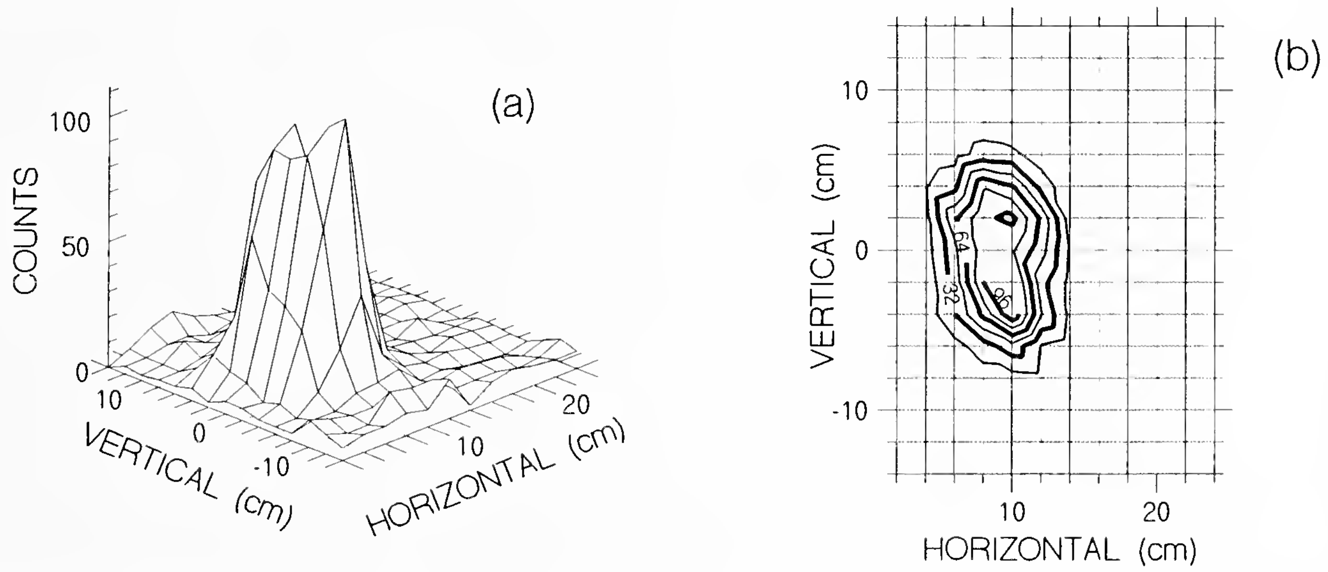

FIGURE 4. A kilogram of a solid cocaine (a) intensity image and (b) contour projection.

The theoretical limit for producing 180 pixel images appears to be ~7.2 seconds. However, at this 25 Hz scanning rate the captured image will be smeared--residual fast decays from previously irradiated pixels will be counted in current pixel count intervals. Desmearing can be accomplished by doubling the current pixel counts and subtracting from subsequent pixels decreasing fractions of the current pixel counts based on the wait-out times, count intervals, and lifetimes involved.

THE NITROGEN CAMERA

Only two additional reactions are produced in appreciable quantity whose products beta decay rapidly, $^{14}N(\gamma,2p)^{12}B$ and $^{14}N(\gamma,2n)^{12}N$, when the accelerator electron energy is increased to 50 MeV. These two reactions together are the nitrogen signal. Nitrogen-12 is a positron emitter with a half-life of 11.0 ms.

To use nitrogen as the marker in screening for explosives, the nitrogen signal must be separated from that of carbon. For samples containing comparable amounts of carbon and nitrogen and excited with 50 MeV electrons each contribute to the signal about equally. For nitrogen-14, the two-proton reaction is ~7

times more probable than the two-neutron reaction (Meyer, Paul, private communication , 1988).

Two promising, but as yet undemonstrated, possibilities for discriminating between carbon and nitrogen reactions are being pursued. The first takes advantage of the differing production thresholds of our three reactions, ~17 for the carbon, and 25 and 30 MeV, respectively, for the two nitrogen reactions. Here the target will be irradiated at 50 MeV until a signal is encountered. Then the beam energy will be reduced to 30 MeV and the promising pixel re-irradiated. These counts, suitably corrected, will provide an estimate of the pixel's carbon and nitrogen content.

The second carbon-nitrogen discrimination method relies on energetic differences in the nitrogen-12 and boron-12 pulse height spectra. Only nitrogen-12 produces 1/2 MeV annihilation gamma rays. Further, nitrogen-12 bremsstrahlung spectra is substantially harder (end-point energy is ~17 MeV) than that of boron-12 (~13 MeV) and so has more high-energy gamma rays. Setting discriminator levels on the detector pulse heights, we can obtain three spectra with energy of 0.4-0.6, 1.0-4.0 and >4.0 MeV. The nitrogen reaction will dominate the first and last, while the second will arise from reactions on both carbon and nitrogen. From these three images the relative amounts of carbon and nitrogen will be determined.

Targets of room air and of ~300 grams of melamine ($C_3N_6H_3$) were irradiated by multiple (~1,500) 1 mA bursts of 50 MeV electrons to produce the time spectra seen in Fig. 5. In the melamine spectrum, which displays the features seen for carbon at 30 MeV, the signal constitutes 17.3 ± 0.5% of the counts and implies a half-life of 18.6 ± 0.6 ms, appropriately between that of nitrogen-12 and boron-12.

Figure 6 shows two intensity images of ~225 grams of potassium nitrate contained in a thin-walled aluminum tube attached to the plate by one of its circular surfaces. In the first, the probing radiation is 30 MeV electrons while in the second the electron energy into the tantalum radiator is 40 MeV. At 30 MeV no evidence of the target is seen above a background of ~3 counts, while at 40 MeV a peak of ~56 counts on a ~12 count background is clearly evident.

An intensity image of 125 grams of the plastic explosive, SEMTEX, with similar shape and orientation as the KNO, is irradiated with 50 MeV electrons, and is clearly seen in Fig. 7. This explosive, less than half that responsible for the Pan Am 103 disaster (Report, 1990), contains carbon and nitrogen in about equal amounts.

PROSPECTS

With the physics of the Carbon and Nitrogen Cameras now established, efforts are underway to test their effectiveness for detecting real concealed drugs and narcotics in controlled blind trials in the laboratory.

However, much still remains to be accomplished before the Carbon and Nitrogen Cameras become practical devices. The image desmearing and carbon-nitrogen discrimination strategies described above must be experimentally verified. Our detectors to date have used a variety of photomultiplier tubes, scintillation materials and geometries which now must be optimized and standardized. Data acquisition must be automated and pattern recognition codes

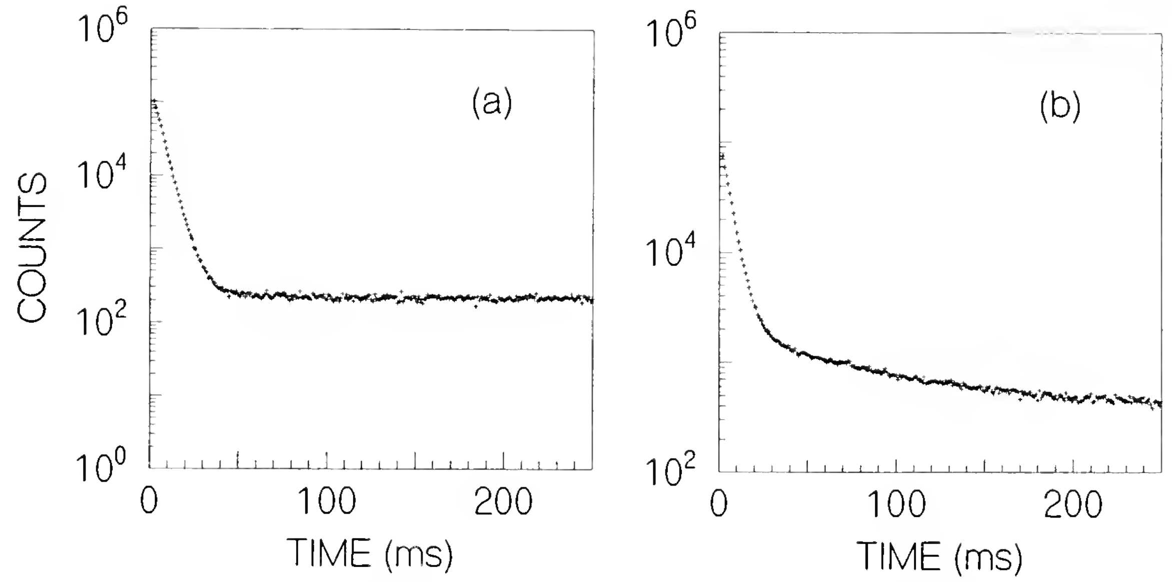

FIGURE 5. Time spectra for 50 MeV electrons on (a) room air and (b) melamine targets.

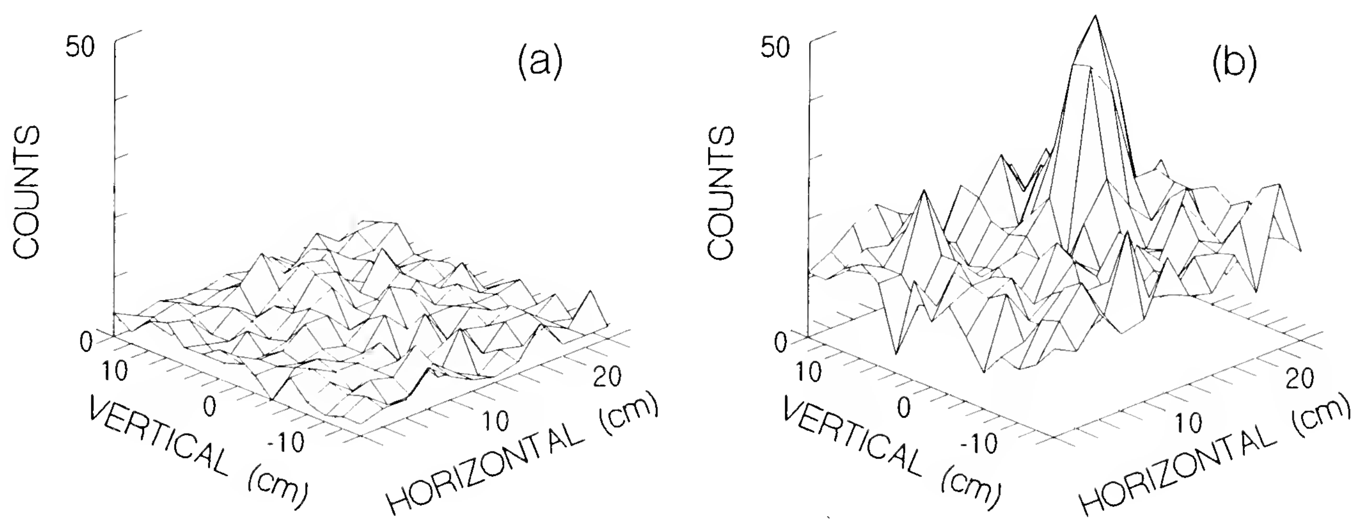

FIGURE 6. Intensity images of a KNO_3 cylinder irradiated at (a) 30 and (b) 40 MeV.

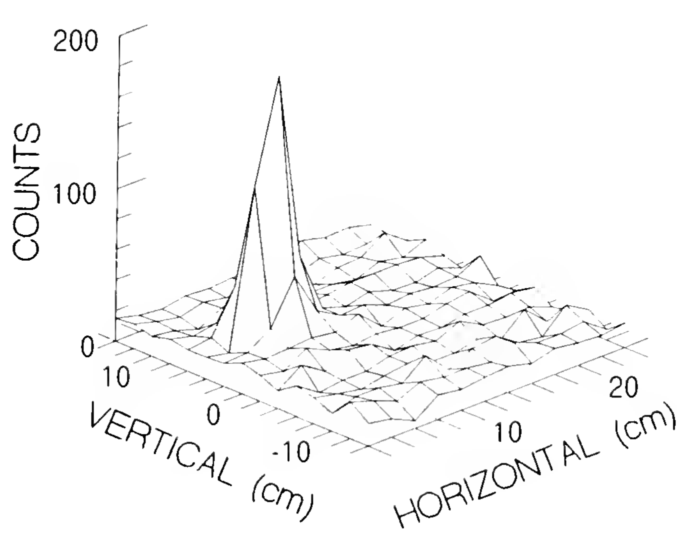

FIGURE 7. Intensity image of a cylinder of SEMTEX irradiated by 50 MeV electrons.

written and evaluated so operator intervention is minimized. The radiation hazard must be re-evaluated and minimized.

The most daunting obstacle to realizing the Carbon and Nitrogen Cameras in a prototype is the lack of an appropriate accelerator with which to produce the photons. No commercial linac has sufficient energy while the sole microtron manufacturer sells sufficiently energetic machines but they are too large and heavy. What is needed is a small, light weight, rugged, reliable microtron which can be vehicle mounted and its operation automated so that it can be controlled remotely. To act as the Nitrogen Camera light source, this machine must be capable of producing 60 MeV pulsed electron beams of 30 mA in 5 μs pulses at a rate of 25 Hz. For the Carbon Camera, the reduced beam energy of 30 MeV makes a small, so-called "shoe-box" accelerator a real possibility. Finally, the cost of these microtrons must be reasonable, more typical of industrial than medical devices. Design studies for such light sources are currently being made with colleagues in Russia (Karev, 1992).

ACKNOWLEDGEMENTS

This work was begun with the late Luis W. Alvarez. In it I have enjoyed generous instrumental support from Dale Schutt, benefited from Robert Moler's wise advice on matters explosive, used well the cocaine provided through the good offices of Willy Boehmer, and prospered from Staffan Rosander and his staff's operation of their racetrack microtron.

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The Worldwatch-Talloires Connection: Meeting a Challenge with a Challenge[1]

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During 1990, while serving on a committee that was reviewing Virginia Tech's[2] university-level core curriculum, I encountered the following statement in the Worldwatch Institute's 1990 *State of the World* report:

> In taking on the task of sketching an environmentally stable society, we have made several important assumptions. The first is that if the world is to achieve sustainability, it will need to do so within the next 40 years. If we have not succeeded by then, environmental deterioration and economic decline are likely to be feeding on each other, pulling us into a downward spiral of social disintegration. Our vision of the future therefore, looks to the year 2030.

Perhaps age provides a vantage point from which to perceive how brief a time 40 years is. The president of the United States who will serve in 2030 is probably 15-19 years old today. At this moment, that future president may well be in some college professor's class. In still other classes--high school or college--are that president's cabinet members, members of congress, state governors and assemblymen, and the community and business leaders of that not-so-distant era.

Having become aware of the Worldwatch's dire prediction, and having already convinced myself of the validity of their argument, I concluded that disseminating their warning to today's students was more important than worrying over the distribution of college credits among the natural and social sciences, and the humanities. This conclusion was transmitted to the Core Curriculum committee in the form of an essay. Using the fate of the Titanic as an analogy, I pointed out that after the ship had been gashed ever-so-gently by an iceberg, only one person--the builder's architect who was on board--realized that the Titanic had but one and one-half hours to remain afloat. The Captain took the architect's warning seriously and gave the order, "Abandon ship". Many passengers, perhaps a majority, sensed no danger during the early moments following the scraping encounter. Only as the *Titanic* filled with water and listed perilously did the truth of the situation strike home to all. By morning, half of the 3000 passengers and crew aboard the stricken ship were dead.

Once submitted to the committee, my essay disappeared from sight--presumably to be exhumed for consideration after the passage of two or three years. To my colleagues, forty years seemingly meant "Not to worry"; the committee had been charged with reviewing the core curriculum, and reviewing the core curriculum it would continue doing.

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1 This is the text of the Sidney Negus Lecture presented by Dr. Wallace to the Academy on May 20, during the 1993 Annual Meeting at Old Dominion University, Norfolk, VA.

2 Throughout this paper, Virginia Polytechnic Institute and State University is refered to as "Tech" or "Virginia Tech".

The biologists at Tech have two seminars, an interdepartmental genetics seminar and an informal evolution seminar, that meet on alternate semesters: genetics in the Fall, evolution in the Spring. Frustrated at the inertia of those who were patiently reviewing the students' core credits, I asked the regular members of the evolution seminar group to expand the scope of the Spring 1991 seminars to cover the Worldwatch Institute's concerns. To be effective, I warned, ethicists, philosophers, and students of religion as well as economists, professors of business, political scientists, and engineers must be invited to participate. With the blessing of the evolutionists, the Worldwatch seminars were initiated.

Early meetings of new seminars were virtually clandestine. Nevertheless, the audience in the Spring of 1991 grew steadily from 25 to more than 100. With no credits weighing on the students' minds, and with no class waiting in the hallway for permission to enter the classroom, discussions were extended and animated. During this first semester, major newspapers carried articles about the Talloires Declaration, a declaration that was signed at the late Jean Mayer's urging by the presidents and senior executive officers of some two dozen universities, worldwide. The signatories of this Declaration agree to certain actions, ten in number, that ensure environmental literacy on the part of their students, informed action on the part of each university with respect to governmental policy and business practices, and--as physical entities--to institutional practices such as conservation and re-cycling that are environmentally kind.

Undergraduates and graduate students who were attending the 1991 Worldwatch seminars persuaded their respective student governing bodies to pass resolutions urging Tech's President-- James McComas--to sign the Talloires Declaration. President McComas took the matter an additional step. Through his initiative, Professor Richard Bambach and I were invited to speak at a meeting of the Presidents' Council, an advisory council of the State Council of Higher Education of Virginia (SCHEV). As a result of our presentations, the college and university presidents constituting the Presidents' Council signed onto the Declaration as a bloc, and urged SCHEV to amend its publication, *Education in the 21st Century*, by including an appendix on environmental matters, an area that earlier had been inexplicably overlooked.

The action taken by Virginia's college and university presidents has had certain consequences. Each college pledges to establish a steering committee charged with responsibility for seeing that the institution does follow up on the other actions that are specified in the Declaration. When the Tech Steering Committee was appointed, Dr. McComas informed the other, statewide signatories that Tech will host an annual meeting of the chairpersons of all other local steering committees; the chairperson of Tech's Steering Committee will be the official host at that annual meeting. A Secretariat will be chosen at the annual meeting; this group can then represent the Commonwealth's institutions vis-a-vis the General Assembly or local industries. Upon hearing of Tech's plans to host an annual, statewide meeting, Anthony Cortese, Dean of Environmental Programs at Tufts University and keeper of the roster of Talloires signatories, asserted that he will inform all Talloires signatories of Tech's annual meeting, and suggest that representatives be sent from institutions throughout the United States, or even worldwide. As an addendum, I might say that the Council of Higher Education in Colorado, at the time of this

writing, is considering signing the Talloires Declaration *en masse*, just as the institutions of higher learning did in Virginia. Several other states including North Carolina and Georgia are apparently considering similar actions.

Over successive semesters, the Worldwatch seminars at Tech have evolved, largely through the efforts of Professors Bambach (who now arranges for the seminar speakers) and Dudley (Director of the University Honors Program), into a coherent program. No longer clandestine, attendance at the Worldwatch seminars (plus a weekly writing assignment) gains Honors Program and other motivated students one hour core credit; each student can repeat this "course" three times, for a total of three coveted core credits. In addition to students who have registered for this minimal credit, there are others who attend out of simple desire to do so; the latter are joined by interested faculty members and townspeople who wish to participate. Several undergraduate and one graduate course have been designed in a manner that requires those who are officially registered to attend the weekly Worldwatch seminars. Finally, the students who have registered in the honors, enrichment sections of the elementary courses that are offered by five departments (Biology, Sociology, English, Political Science, and Philosophy) are urged to attend these seminars, although they are not required to do so.

The Worldwatch attendees form a substantial portion of the audience that is attracted to the annual President's symposia. Upon his arrival at Tech in 1988, Dr. McComas requested that the Distinguished Professors organize an annual symposium (now known as the President's Symposium) around a timely topic of global interest. The first four of these symposia have dealt with global warming, AIDS, drugs and the law, and professional ethics.

Almost by definition, the topics discussed by the symposia speakers are those that bear on environmental matters of concern to Worldwatch speakers and their audiences. The Fifth Annual President's Symposium to be held on Thursday, September 23, 1993, for example, celebrates the wholesale signing of the Talloires Declaration by the college and university presidents of Virginia. Among the participating speakers will be Daniel Quinn, author of Ishmael, Anthony Cortese "caretaker" of Talloires signatories, Charles Knapp, President of the University of Georgia, and Marcia Lowe, representing the Worldwatch Institute.

Thus, by virtue of the Worldwatch program, obligations assumed under the Talloires Declaration, and the annual President's Symposium, students at Virginia Tech are exposed to a wide range of views concerning the huge problems that must be successfully confronted if a sustainable society (dwelling, if possible, in the complex natural environment to which we are accustomed) can be attained. The Worldwatch seminars do not dwell on techniques for managing the environment; technical training is best left to the professional departments. The most serious problems facing us all as members of the world community, however, are not technical ones; the truly difficult ones involve attitudes and behavior. They involve such matters as greed, racism, aggression, bigotry, and ethics. Because no one profession nor any one person has the wisdom to arrive at or the power to enforce the needed societal changes, an integrated (i.e., wholly multidisciplinary) educational effort such as that encouraged by the Worldwatch program is needed. I cannot claim that we have reached every student. I cannot claim that I have enlisted every faculty member to help in this huge task. I am endeavoring, however, to

remove ignorance as an excuse for inaction, or as a lament to be uttered 40 years from now if a sustainable society has not emerged, or has been designed too late.

At this point I would like to digress momentarily. A recent article by Professor John R. Searle that was published in a Bulletin of the American Academy of Arts and Sciences states that an important assumption made by humanists is that in the real world there are truths corresponding to the humanists' utterings. I would like to emphasize here my own desire that there be a reality that corresponds to my utterings. There is a partial correspondence; that I know from personal observation. But, the correspondence could be much better.

When the topic under discussion concerns the potentially irreversible harm that may severely afflict the earth within the next forty years, one would expect to generate more interest than that suggested by audiences of 75-100 students from a student body that exceeds 20,000. Or a half-dozen professors from a faculty of nearly 2,000. The massive proportion of absentees demands an explanation. I can enumerate several possible ones:

1. Information of the sort generated by the Worldwatch Institute has not yet reached (or has not been grasped by) academics in all fields. Major newspapers may carry relevant news stories virtually every day, but the linkage between these depressing stories and topics such as those covered by the Worldwatch seminars is implicit rather than explicit. Many persons fail to see the underlying connections. A professor of business management, for example, accepted an invitation to speak in the Worldwatch series, but denied that there existed any connection between his field of expertise and environmental matters.

2. Many persons disbelieve the Worldwatch warning. The same, as I mentioned earlier, was true of many passengers aboard the Titanic. Such persons are desperately needed in the seminar audience in order to broaden the discussions to which attending audiences are exposed. Unfortunately, academic disputes and intellectual confrontations are for many persons physically, emotionally, and mentally wearing, and are to be avoided--not sought out--if possible.

3. Professor Alfred Kahn's "tyranny of small decisions" can be re-phrased in the present context to read: "the tyranny of small activities. " Parkinson's law states that work expands to fill the time available for its completion. The Worldwatch seminars, despite the urgency of the problems they address, must compete for time in otherwise saturated daily schedules-- however trivial each moment's task may be.

4. Most students, in the final analysis, take their cues from their professors. If departmental seminars are poorly attended by faculty members, they will be poorly attended by students, as well. The converse has been amply confirmed at past Worldwatch seminars: participating faculty members have often been accompanied by a coterie of their own students who then disappeared never to return.

5. Class conflicts prevent many interested students and faculty members from attending; under current scheduling procedures such conflicts would seem to

be inevitable. Indeed, compiling a course schedule that is free of conflicts is a major task that confronts every undergraduate every school term.

The last point ends my digression while providing me an opportunity to issue a challenge to the academic administrators of all colleges and universities--including my own. Consider the following facts: Life on earth arose some 3.6 billion years ago; pre-human apelike creatures arose some 10 million years ago; Neanderthal men and women were thriving 100,000 years ago; and agriculture has flourished for the past 10,000 years. If the time that life has existed on earth is equated to one year, each day represents 10 million years. Each of the nearly 100,000 seconds in a day represents 100 years. Thus, apelike creatures appeared only on December 31st, after the earlier 364 days of life's year were gone. Neanderthals flourished only during the last 2-3 hours of the last day--beginning, let us say, at 9 PM on December 31st. Human society as we have known it since Egypt and Babylonia has existed for two minutes only--civilization arose at 11:58 PM--only moments before midnight on New Year's Eve.

Huge numbers of persons--scientists and others--have warned us during the past two or three seconds of this fateful year that the number of persons (nearly 6 billion at the latest count, but increasing by 100 million annually) is threatening lifesustaining relationships and biological interactions that have taken months (that is, hundreds of millions of years) to arise, adjust to one another, and to fall into place. This ecological network of interactions supports human beings as well as other forms of life, even though our technological and industrialized society, and our preoccupation with political matters may conceal that fact. These concerned, knowledgeable persons have given us less than a half-second--an eye blink--in which to act.

My challenge to academic administrators is this: Given the importance of the issues described here, create a weekly two-hour period that is free of any other officially sanctioned faculty or student activity, and dedicate this period to a campus-wide discussion of vital, global issues. Remove from these two hours all conflicting activities such as classes, departmental seminars, committee meetings, and administrative conferences. I make this challenge while providing two loopholes by which those whom I have challenged may escape: First, they may escape by providing a thoughtful, written document stating why they disbelieve the urgency of the matter, a document that can be studied and possibly rebutted publically by those of us who are truly concerned. Second, they may escape by providing a formal, mathematically-valid proof that no 2-hour, school-day period at a college or university can be set aside and declared to be free of all other official activities. I make these challenges, neither in a mean or disgruntled spirit nor in pique, but rather in an attempt to provide a permanent, written account of what was attempted during the 1990s at our institutions of higher learning with respect to environmental instruction. Historians of the 2030s and later years will appreciate having such contemporary accounts available for their research.

My concluding point will be as heretical as the challenge that I have leveled above at college and university administrators. I contend that no science, no profession, no technology, and no philosophy or religion has the innate wisdom to solve, on its own, the grave problems confronting the modern world. Neither the

professions alone nor their associated professional ethics are adequate for the task. This assertion, I might emphasize, includes medicine and medical ethics; I make this point explicit because many persons regard medical ethics with a reverence generally reserved for the Holy Book.

It appears to me, then, that no general, elementary, departmental course (beginning biology, beginning chemistry, beginning physics, basic engineering, or whatever) provides the incoming college freshman or woman with an overview that is adequate for today's world. A multidisciplinary survey course in Environmental Literacy must be made available for all. A course that provides each student with an understanding of the earth's origin, the evolution of life, and of the human lineage. A course that convincingly demonstrates the inadequacy of any one profession or professional ethic to cope with existing and everworsening problems. A course whose content is consistent with the established laws of thermodynamics; one that avoids fanciful solutions to pressing problems--no rocketing of solid wastes to the moon, no habitation of Mars, no creation of needed elements by splitting atomic nuclei, and no genies who emerge from lamps prepared to grant every human's wish. And, finally, a course that emphasizes the unity of the human species even while extolling its diversity. A course emphasizing that cultures are not indivisible units but, rather, are entities that are composed of *ideas* which recombine, but do not disappear, when cultures fuse. Thus, variation is not lost by the admixture of cultures; rather, *inter*-culture variation is merely transformed into *intra*-culture variation.

In concluding, I emphasize once again that in my opinion-- and in that of thousands of scientists--the specter of what may happen to our world during the next forty years--irreversible, tragic happenings--virtually demands that specialized, departmental introductory courses be regarded solely as part of one's professional training at colleges and universities. The student's training for living within a sustainable society must be met by a broadly based, multidisciplinary course on environmental literacy--a course that will exclude no branch of intellectual endeavor, be it in the sciences, the professions, the humanities, or the arts.

University Presidents for a Sustainable Future
The Talloires Declaration

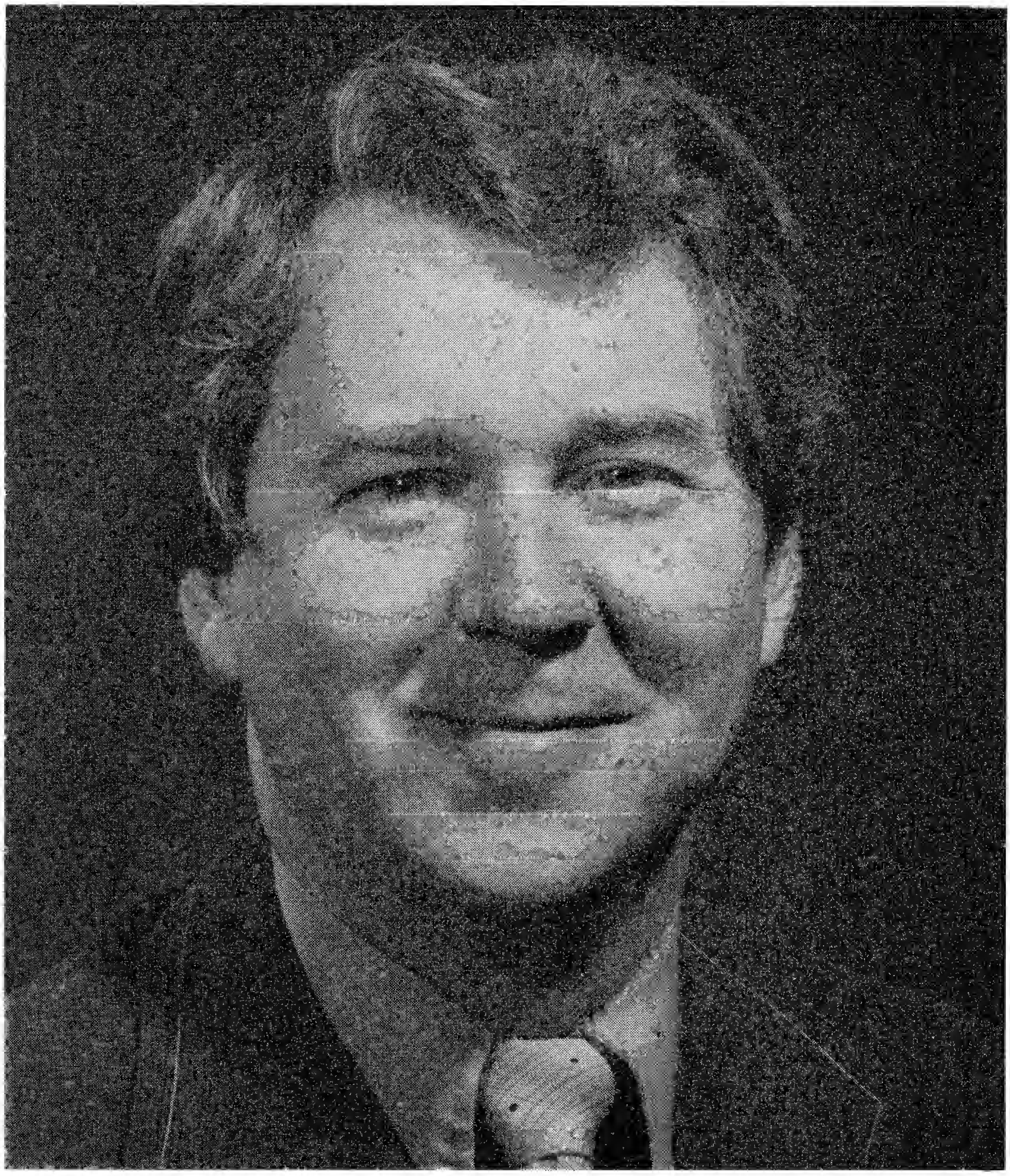
We, the presidents, rectors, and vice chancellors of universities from all regions of the world are deeply concerned about the unprecedented scale and speed of environmental pollution and degradation, and the degradation of natural resources. Local, regional. and global air and water pollution; accumulation and distribution of toxic wastes; destruction and depletion of forests, soil, and water; depletion of the ozone layer and emission of "greenhouse" gases threaten the survival of humans and thousands of other living species, the integrity of the earth and its biodiversity, the security of nations, and the heritage of future generations. These environmental changes are caused by inequitable and unsustainable production and consumption patterns that aggravate poverty in many regions of the world.

We believe that urgent actions are needed to address these fundamental problems and reverse the trends. Stabilization of human population, adoption of environmentally sound industrial and agricultural technologies, reforestation, and ecological restoration are crucial elements in creating an equitable and sustainable future for all humankind in harmony with nature. Universities have a major role in the education, research, policy formation, and information exchange necessary to make these goals possible.

University heads must provide the leadership and support to mobilize internal and external resources so that their institutions respond to this urgent challenge. We, therefore, agree to take the following actions:

1. Use every opportunity to raise public, government, industry, foundation, and university awareness by publicly addressing the urgent need to move toward an environmentally sustainable future.
2. Encourage all universities to engage in education, research, policy formation, and information exchange on population, environment, and development to move toward a sustainable future.
3. Establish programs to produce expertise in environmental management, sustainable economic development, population, and related fields to ensure that all university graduates are environmentally literate and responsible citizens.
4. Create programs to develop the capability of university faculty to teach environmental literacy to all undergraduate, graduate, and professional school students.
5. Set an example of environmental responsibility by establishing programs of resource conservation, recycling. and waste reduction at the universities.
6. Encourage the involvement of government (at all levels), foundations, and industry in supporting university research, education, policy formation, and information exchange in environmentally sustainable development. Expand work with non-governmental organizations to assist in finding solutions to environmental problems.
7. Convene school deans and environmental practitioners to develop research, policy, information exchange programs, and curricula for an environmentally sustainable future.
8. Establish partnerships with primary and secondary schools to help develop the capability of their faculty to teach about population, environment, and sustainable development issues.
9. Work with the U.N. Conference on Environment and Development, the U.N. Environment Programme, and other national and international organizations to promote a worldwide university effort toward a sustainable future.
10. Establish a steering committee and a secretariat to continue this momentum and inform and support each other's efforts in carrying out this declaration.

The Virginia Academy of Science
Ivey F. Lewis
Distinguished Service Award



Harold Morton Bell

Distinguished chemist, dedicated teacher, and staunch supporter of the Virginia Academy of Science, Harold Morton Bell is representative of the best traditions of the Academy. In honoring him with the Ivey F. Lewis Distinguished Service Award, the Academy simply recognizes a devotion to its ideals that is deeply felt by every member of our organization.

A native of Monticello, Kentucky, Dr. Bell was graduated from Eastern Kentucky University in 1960 with the degree of Bachelor of Science. He undertook his graduate work at Purdue University receiving the Ph.D. degree in chemistry in 1964. He worked briefly for the U. S. Army before coming to the Department of Chemistry at the Virginia Polytechnic Institute and State University, where he has served throughout his career.

In his professional capacity Dr. Bell has specialized in the chemical reactions of the metal hydrides. He has pioneered in the application of nuclear magnetic resonance spectroscopy and computer techniques to problems of chemical analysis. He has published numerous papers on these subjects in such professional organs as the Journal of the American Chemical Society and the Journal of Organic Chemistry.

Dr. Bell has spent much of his energy in improving the quality of education in his home institution. His contributions have been recognized by the award of the VPI & SU Certificate of Teaching Excellence in 1979 and the Nan F. Clifford Service Award of the Department of Chemistry in 1985. His papers in the Journal of Chemical Education attest to his interest in applying his expertise in NMR and computer analysis to the classroom.

Ever since his arrival at VPI & SU Dr. Bell has taken an active interest in the Virginia Academy. He has held all the offices in the Chemistry Section, Secretary, Councilor, and Chairman. He has served on numerous committees, among them the Junior Academy Committee, the Membership Committee, the Committee on the Science Museum of Virginia, and the Nominations and Elections Committee. He has held our highest office as President in 1982-1983.

With all these, his greatest service to the Academy has yet to be mentioned: his long and persevering tours of duty as the Director of the Visiting Scientist Program from 1979 to 1982 and from 1985 to 1992. In this office, largely out of sight of the majority of Academy members, Dr. Bell has worked tirelessly to collect and publish lists of topics and speakers from Virginia's Colleges and Universities. The lists are distributed to science supervisors and teachers in order to bring the expertise and enthusiasm of working scientists to the high schools of the Commonwealth. As those who are familiar with the program will realize, the work is always a struggle against the logistical problems of getting the right information to the right people at the right time, and often a battle against the apathy of overloaded teachers and administrators.

In recognition of his long, dedicated, and fruitful service to the Virginia Academy of Science and to the Commonwealth of Virginia, the Academy hereby awards to Harold Morton Bell the Ivey F. Lewis Distinguished Service Award for 1993.

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